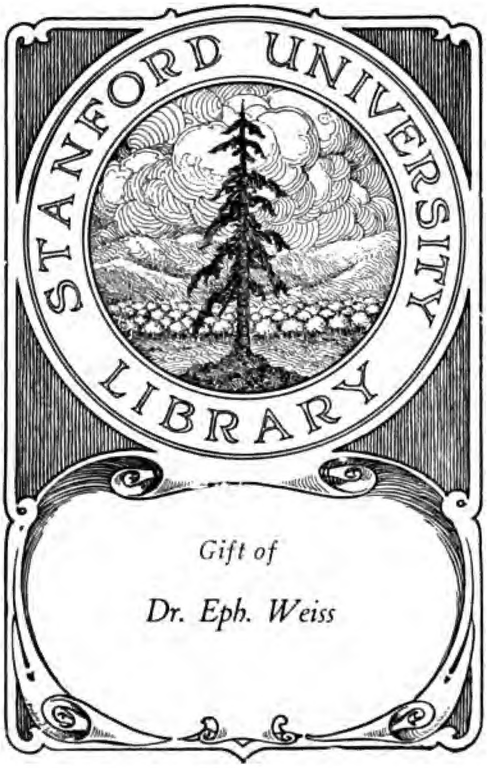

DVENIT
TERRA AUTEM IN ÆTERNUM STAT
EPH. WEISS
GENERATIO PRÆTERIT, ET GENE



PRINCIPLES OF GEOLOGY

VOL. II.

Frontispiece

See p. 167.

BAY OF BAIÆ, NEAR NAPLES.

(Sir W. Hamilton, Campi Phlegræi, Plate 26.)

1. Puzzuoli. 2. Temple of Serapis. 3. Caligula's Bridge. 4. Monte Barbaro. 5. Monte Nuovo. 6. Baths of Nero. 7. Baiæ. 8. Castle of Baiæ. 9. Bauli. 10. Cape Misenum. 11. Monte Eporneo in Ischia. 12. South Part of Ischia

PRINCIPLES OF GEOLOGY

OR THE

MODERN CHANGES OF THE EARTH AND ITS INHABITANTS

CONSIDERED AS ILLUSTRATIVE OF GEOLOGY

By SIR CHARLES LYELL, Bart., M.A., F.R.S.

'Verè scire est per causas scire'—Bacon

'The stony rocks are not primeval, but the daughters of Time'—Linnæus, *Syst. Nat.* ed. 5, *Stockholm*, 1748, p. 219

'Amid all the revolutions of the globe the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same'—Playfair, *Illustrations of the Huttonian Theory*, § 374

ELEVENTH AND ENTIRELY REVISED EDITION

In Two Volumes—Vol. II.

Illustrated with Maps, Plates, and Woodcuts

NEW YORK:
D. APPLETON AND COMPANY,
549 & 551 BROADWAY.
1876.

PREFACE

TO

THE ELEVENTH EDITION.

As only three years have elapsed since the last edition of this Second Volume of the 'Principles' was published, I have been able to reprint it with less alteration than was required in the First Volume, between which and the preceding edition there had been an interval of five years.

I have followed the rule adopted in my First Volume of reprinting the Preface to the tenth edition, by which the reader will be directed to those numerous and important additions and corrections which I found necessary in consequence of the progress of the science during the fifteen years which separated the ninth and tenth editions. Although the pages after the first two hundred differ slightly in the present edition, they are not so much altered as to render it difficult to refer to them.

I subjoin a list of the most important points on which I have introduced new information in the present edition.

PREFACE

TO

THE TENTH EDITION.

In the Preface to the First Volume I gave a list of the dates of publication of the successive editions of this treatise, as well as of my 'Elements of Geology' and my 'Antiquity of Man,' and pointed out the relation of these two last works to the 'Principles.'

In the same Preface I gave a list of the chief additions then made for the first time; pointing out, so far as was possible, the corresponding pages in the ninth edition; so that readers already familiar with the earlier editions might be able at once to refer to what was new.

I now subjoin a similar list of the chief alterations and additions introduced for the first time into this tenth edition.

List of the Principal Additions and Corrections in the Second Volume of the Tenth Edition of the 'Principles of Geology.'

Ninth Edition.	Tenth Edition.	Additions and Corrections.
Page 396 to 424.	Page 1 to 47	Considerable additions have been made to this Twenty-sixth Chapter, on the structure of Mount Etna, in consequence of my re-examination in 1857 and 1858 of this volcano, which I had first visited thirty years before, in 1828. The theory of a double axis of eruption is explained (p. 9), and the changes in the scenery of the Val del Bove, caused by the lavas of 1852, are described (p. 31). The solid texture and steep original inclination of certain lavas of known date are pointed out (pp. 35 & 36). The relation of some ancient valleys on Etna to the former structure of the mountain is considered (p 40).

Ninth Edition.	Tenth Edition.	Additions and Corrections.
Page	Page	
	•	Eleven new woodcuts illustrate Chapter XXVI., borrowed chiefly from my paper on Etna, communicated to the Royal Society in 1858.
444	69	An account is here given of the changes produced by the recent eruption in the Gulf of Santorin in February 1866, with a bird's-eye view of the same.
452	82 to 89	An account of the earthquake in New Zealand in 1855, and the permanent upheaval and subsidence of land in that archipelago, is given on the authority of Messrs. Roberts, Walter Mantell, and F. A. Weld. A new fault or shift of 9 feet in the rocks is described. A map of the region convulsed by the same earthquake is appended.
488	135 to 140	In reference to the earthquakes in Calabria in 1783 and 1857, the origin and mode of the propagation of earthquake waves is treated of, and illustrated by three new diagrams. Some account is given of Mr. Robert Mallet's proposed method of calculating mathematically the depth in the earth's crust from which the shocks may proceed.
494	146	Junghuhn on the truncation of the cone of Papandayang in Java.
529	187	Recent observations made to determine whether a change is going on in the relative level of land and sea in Sweden.
527	192	Messrs. Gwyn Jeffreys and Torell on shells of the Glacial Period in the Uddevalla district in Sweden.
542	208	The hypothesis of a change in the axis of rotation of the external shell of the earth considered as a possible cause of change of climate.
538 to 542	209 to 213	This Thirty-second Chapter has been in part re-written and enlarged. It is shown that the old notion, that the crystalline rocks, whether stratified or unstratified, such as granite and gneiss, were produced in the lower part of the earth's crust, at the expense of a central nucleus cooling from a state of fusion, must be given up, now that granite is found to be of all ages, and the metamorphic rocks to be altered sedimentary deposits, implying the denudation of a previously solidified crust.
542 to 544	225 to 234	The Thirty-third Chapter has been in great part recast. It is shown that the latest chemical observations on the products of recent eruptions favour the doctrine, that large bodies of salt water gain access, during an eruption, to the volcanic foci. The reservoirs of melted matter in the interior, though vast, may hold a very subordinate place in the earth's crust.
		The heat supposed to be continually lost by the planet by radiation into space, may perhaps be restored by solar magnetism in connection with electricity and chemical action.
Chap. xxxiv. in part.	261 to 283	The greater part of this Thirty-fifth Chapter is new. The objections originally urged against Lamarck's theory of transmutation and his replies are considered. Also the question whether, if new species are created from time to time, their first appearance would have been witnessed by the naturalist. Remarks are offered on the 'Vestiges

Ninth Edition.	Tenth Edition.	Additions and Corrections.
Page	Page	
		of Creation,' and on the theory of 'Natural Selection,' as advocated by Mr. C. Darwin and Mr. A. Wallace. The change of opinion produced by Mr. Darwin's work on 'The Origin of Species' is pointed out, and Dr. Hooker's views on the formation of species in the vegetable world by variation and selection are noticed.
592 593 595 597 600 to 607	284 to 315	This Thirty-sixth Chapter is for the most part new. It contains an explanation of Mr. Darwin's views on the formation of new races by selection, both unconscious and methodical, whether of plants or animals under domestication. His doctrine of 'Pangenesis,' or the manner in which long-lost characters may be revived in the offspring or cross-breeds, is also alluded to. Likewise the fact that certain parts of animals or plants may be made to vary by selection, while other parts of the same remain unaltered. The hybridisation of plants and animals is also considered in its bearing on the nature and origin of species.
605	316 to 328	This Thirty-seventh Chapter is also for the most part new. It treats of natural as compared to artificial selection. The tendency of species to multiply beyond the means of subsistence, the struggle for life, and the conditions on which 'the survival of the fittest' depends, are explained. The opinions of Linnæus, de Candolle, and Darwin on species are compared. It is shown that alternate generation will not explain the mode of origin of new species.
629 to 634	329 to 353	Chapter Thirty-eight, on the geographical distribution of species, has been re-written. The six great provinces of distinct species of terrestrial mammalia are chiefly dwelt upon, and the agreement of the limitation of the species of birds and reptiles, and even of the invertebrate animals generally, to the same regions, is pointed out.
636 to 646	354 to 368	Chapter Thirty-nine, on the migration and diffusion of terrestrial animals, is re-printed, with a few slight additions and corrections, from the ninth edition.
637	358	This woodcut of the Lemming or Lapland Marmot, taken from a specimen now living in the Zoological Gardens of London, has been substituted for a less faithful representation of the same animal given in former editions.
646 to 657 and 613 to 628	369 to 401	The Fortieth Chapter, on the geographical distribution and migration of fish, testacea, insects and plants, is for the most part the same as in the ninth edition. But the following additions and alterations have been made:— Species of marine shells and fishes on opposite sides of the Isthmus of Panama, p. 370. Moths seen flying 300 miles from land, p. 380. Sir C. Bunbury on plants of the Table-land of Brazil, p. 385. Darwin on seeds and fruits immersed in salt water without injury, p. 391. Robert Brown on source of the gulf-weed or sargassum, p. 392.
	396	Darwin on seeds transported by birds, p. 396.
	402 to 432	The Forty-first Chapter is entirely new. It treats of insular floras and faunas considered with reference to the origin of species. The islands of the Eastern Atlantic, especially the Madeiras and Canaries, their volcanic origin and Miocene age, are first treated of, and then the extent to

Ninth Edition. Page	Tenth Edition. Page	Additions and Corrections.
		which the species of mammalia, birds, insects, land-shells and plants, agree or do not agree with continental species. The identity or non-identity, also, of species of all these classes found in different archipelagos or in different islands of the same archipelago, is shown to bear an unmistakable relation to the facilities enjoyed by each class of crossing the ocean. The bearing of this relationship on the theory of the origin of species by variation and 'natural selection' is pointed out.
689 to 701	433 to 463	The Forty-second Chapter, on the extinction of species, is re-printed from the old edition with some few additions, among which may be mentioned the following:—Dr. Hooker on extermination of plants in St. Helena, pp. 453 and 462. Mr. Travers on the spread of foreign plants in New Zealand, p. 453.
660 to 663	464 to 494	The whole of this Forty-third Chapter, on man, considered with reference to his origin and geographical distribution, is new, with the exception of the first five pages.
		The antiquity of the more marked human races, and the coincidence of their geographical range with that of the chief zoological provinces, are considered. The question as to the multiple origin of man is discussed. The bearing of the theory of progressive development and of Darwin's theory of natural selection on the derivation of man from the inferior animals, is treated of.
746	535	Some remarks on the submarine forest at Bournemouth, on the south coast of Hampshire, are added.
	536	Dr. Dawson's description of a submarine forest on the Bay of Fundy is introduced here.
765	557	A brief sketch is given, in retrospective chronological order, of the remains of man and his works which belong to the ages of Bronze and Stone. Implements of the Neolithic Period—of the antecedent Rein-deer Period—and lastly of the Palæolithic Period, are mentioned. The position of flint tools of Palæolithic age in the drift of the southern coast of Hampshire and the Isle of Wight, is explained.
	564	The age of the pottery in the upraised marine strata near Cagliari, on the south coast of Sardinia, is discussed.
775 to 797	579 to 611	The Forty-ninth Chapter is re-printed from the corresponding or concluding Chapter of the ninth edition, with some corrections in the nomenclature of corals supplied by Dr. Duncan, and some observations at p. 580 on the depths at which different genera grow. Allusion is also made, p. 609, to the large quantity of limestone in the oldest or Laurentian series of rocks in Canada.

CHARLES LYELL.

73 Harley Street:
March 1, 1868.

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CHAPTER XXVI.

ETNA.

EXTERNAL PHYSIOGNOMY OF ETNA—LATERAL CONES—THEIR SUCCESSIVE OBLITERATION—MARINE STRATA AT BASE OF ETNA OF NEWER PLIOCENE DATE—OLDEST VOLCANIC ROCKS OF SAME DATE—FOSSIL PLANTS OF LIVING SPECIES IN ANCIENT TUFFS OF ETNA—VAL DEL BOVE ON THE EASTERN FLANK OF ETNA—INTERNAL STRUCTURE OF THE MOUNTAIN AND PROOFS OF A DOUBLE AXIS OF ERUPTION—WANT OF PARALLELISM IN THE ANCIENT LAVAS—DIKES IN THE VAL DEL BOVE, THEIR FORM AND COMPOSITION—TRUNCATION OF THE GREAT CONE—ERUPTIONS OF ETNA OF HISTORICAL DATE—ERUPTION OF MONTI ROSSI, 1669—SCENERY OF THE VAL DEL BOVE—ERUPTIONS OF 1811 AND 1819—THAT OF 1852—CHANGES WHICH IT HAS EFFECTED IN THE VAL DEL BOVE—CASCADES OF LAVA IN THE VAL DI CALANNA—INCLINED LAVA OF CAVA GRANDE—FLOOD PRODUCED BY THE MELTING OF ICE IN 1755—GLACIER PRESERVED BY A COVERING OF LAVA—ANCIENT VALLEYS OF ETNA—ANTIQUITY OF THE CONE OF ETNA.

External physiognomy of Etna.—Next to Vesuvius, our most authentic records relate to Etna, which rises near the sea in solitary grandeur to the height of nearly 11,000 feet.* The base of the cone is almost circular, and 87 English miles

* In 1815, Captain Smyth ascertained, trigonometrically, that the height of Etna was 10,874 feet. The Catanians, disappointed that their mountain had lost nearly 2,000 feet of the height assigned to it by Recupero, refused to acquiesce in the decision. Afterwards, in 1824, Sir J. Herschel, not being aware of Captain Smyth's conclusions, determined by careful barometrical measurement that the height was 10,872½ feet. This singular agreement of results so differently obtained was spoken of by Herschel as 'a happy accident;' but Dr. Wollaston remarked that 'it was one of those accidents which would not have happened to two fools.

in circumference; but if we include the whole district over which its lavas extend, the circuit is probably twice as great.

The cone is divided by nature into three distinct zones, called the *fertile*, the *woody*, and the *desert* regions. The first of these, comprising the delightful country around the skirts of the mountain, is well cultivated, thickly inhabited, and covered with olives, vines, corn, and fruit trees. Higher up, the woody region encircles the mountain—an extensive forest six or seven miles in width, affording pasturage for numerous flocks. The trees are of various species, the chestnut, oak, and pine being most luxuriant; while in some tracts are groves of cork and beech. Above the forest is the desert region, a waste of black lava and scoriæ, which terminates upwards in a kind of table-land, from which rises the principal cone, 1,100 feet high, emitting continually steam and sulphureous vapours, and in the course of almost every century several streams of lava.

Cones produced by lateral eruption.—The most grand and original feature in the physiognomy of Etna is the multitude of minor cones which are distributed over its flanks, and which are most abundant in the woody region. These, although they appear but trifling irregularities when viewed from a distance as subordinate parts of so imposing and colossal a mountain, would, nevertheless, be deemed hills of considerable altitude in almost any other region. Without enumerating numerous monticules of ashes thrown out at different points, there are about 200 of these secondary volcanos as laid down in Von Waltershausen's map within a circuit twenty geographical miles in diameter having the summit of Etna as a centre. Outside of this circular area are a few other modern cones of large size, such as the double hill near Nicolosi, called Monti Rossi, formed in 1659, which is 450 feet high, and two miles in circumference at its base. Although this hill somewhat exceeds in size Monte Nuovo, described in the twenty-fourth chapter, it only ranks as a cone of the second magnitude amongst those produced by the lateral eruptions of Etna. Monte Minardo near Bronte, on the east of the great volcano, is upwards of 700 feet in height.

On looking down from the lower borders of the desert

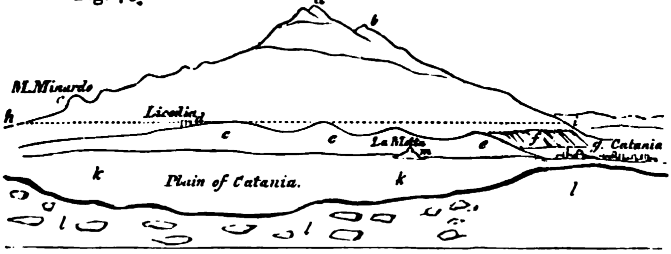
region, these minor volcanos present us with one of the most delightful and characteristic scenes in Europe. They afford every variety of height and size, and are arranged in beautiful and picturesque groups. However uniform they may appear when seen from the sea, or the plains below, nothing can be more diversified than their shape when we look from above into their craters, one side of which is generally broken down. There are, indeed, few objects in nature more picturesque than a wooded volcanic crater. The cones situated in the higher parts of the forest zone are chiefly clothed with lofty pines; while those at a lower elevation are adorned with chestnuts, oaks, and beech trees.

Successive obliteration of these cones.—The history of the eruption of Etna, imperfect and interrupted as it is, affords us, nevertheless, much insight into the manner in which a large part of the mountain has successively attained its present magnitude and internal structure. The cone from which the eruptions at the summit now proceed, has more than once been destroyed either by explosion or engulphment, and has been as often reproduced. The great platform (No. 2, Plate V., and *a*, *b*, *c*, fig. 85, p. 20) seems to have resulted from the truncation of the ancient conical mountain, the uppermost part of which has disappeared during a succession of such catastrophes, leaving a comparatively level ground from which the modern cone now springs.

By far the greater number of eruptions proceed from the great crater *a*, fig. 85, and from lateral openings in the desert region. When hills are thrown up lower down or in the middle zone, and project beyond the general level, they gradually lose their height during subsequent eruptions; for when lava descending from the upper parts of the mountain encounters any of these hills, the stream is divided, and flows round them so as to elevate the gently sloping grounds from which they rise. In this manner a deduction is often made at once of twenty or thirty feet, or even more, from their height. Thus, one of the minor cones, called Monte Peluso, was diminished in altitude by a great lava stream which encircled it in 1844; and another current has recently taken the same course—yet this hill still remains 400 or 500 feet high.

There is a cone called Monte Nucilla near Nicolosi, round the base of which several successive currents have flowed, and showers of ashes have fallen in historical times, till at last, during an eruption in 1536, the surrounding plain was so raised, that the top of the cone alone was left projecting above the general level. Monte Nero, situated above the Grotta dell' Capre, was in 1766 almost overflowed by a current: and Monte Capreolo afforded, in the year 1669, a

Fig. 76.



View of Etna from the summit of the limestone platform of Primosole, looking north.

a. Highest cone.
b. Montagnuola.
c. Monte Minardo, with smaller lateral cones above.
d. Town of Licodia dei Monaci.
e. Argillaceous and sandy beds with marine shells, nearly all of living Mediterranean species, and with associated and contemporaneous volcanic rocks.
f. Escarpment of stratified subaqueous volcanic tuff, &c., north-west of Catania.
g. Town of Catania.
h, *i*. Dotted line expressing the highest boundary along which the marine strata are occasionally seen. They reach at Catira, 4 miles north of Catania, a height of about 1,258 English feet above the level of the sea.
k. Plain of Catania.
l. Limestone platform of Primosole of the Newer Pliocene period.
m. La Motta di Catania.

curious example of one of the last stages of obliteration; for a lava stream, creeping along the top of a ridge which had been built up by the continued superposition of successive lavas, flowed directly into the crater, and nearly filled it. The lava, therefore, of each new lateral cone tends to detract from the relative heights of lower cones above their bases; so that the flanks of Etna, sloping with a gentle inclination, envelope in succession a great multitude of minor volcanos, while new ones spring up from time to time.

Marine strata and volcanic rocks of Etna of Newer Pliocene date.—In the annexed outline of Etna and its environs, which I made in 1828 from the platform of tertiary limestone of Primosole, the summit of the volcano is seen 24 geogra-

phical miles distant in a straight line. At our feet lies the alluvial plain of Catania (*k*) 6 miles broad, through which the Simeto runs, and which is bounded on the north by an undulating country, *e*, *e*, composed for the most part of a marine tertiary deposit of Newer Pliocene age.

The district composed of it near Catania which is provincially called 'Terra Forte,' must have emerged from beneath the sea at a period of very modern date geologically speaking; for not only are almost all the fossil shells, included in the clays, of recent species, but the argillaceous beds themselves are capped at the height of nearly 1,000 feet by two deposits, in one of which near the sea all the shells are of living species, while the other consists of rounded pebbles of limestone and other rocks evidently once brought down from the interior by the Simeto and deposited in its delta, which delta was afterwards uplifted together with the subjacent clay as well as the neighbouring mass of Etna and the sea-coast at its base. In the old alluvium here adverted to, the bones of elephants and other extinct mammalia have been found at several points. The line *h*, *i*, expresses the level at which the marine Newer Pliocene formation crops out irregularly from beneath the modern streams of volcanic matter which are gradually encroaching upon it and concealing it more and more from view. Sometimes it cannot be traced higher than 600 feet, but at one place called Catira, 4 miles north of Catania, the marine clays have been detected at the height of 1,258 English feet above the level of the Mediterranean. At that point and along the adjoining coast, as at Aci Castello and at Trezza opposite the Cyclopean islands, and at Nizzeti a mile and a half north-west of Trezza, the fossiliferous clays are associated with contemporaneous basaltic and other igneous products, the most ancient monuments of volcanic action within the region of Etna. By these eruptions the foundations of the great volcano may be said to have been laid in the sea when the present site of Etna was a bay of the Mediterranean. The fossil shells therefore found in these clays are of great interest in settling the chronology of the older part of the mountain. Out of 65 species which I myself collected in 1828 M. Deshayes considered 4 to be

extinct and the rest now common in the Mediterranean. Philippi in 1844 obtained from the same district 76 species, of which only 3 were extinct, while he found that a larger number (109) from Cefali in the suburbs of Catania yielded a proportion of about 6 per cent. of extinct as compared to living species. A still larger collection of 142 species of shells which Dr. Aradas kindly lent to me in 1858 yielded 8 per cent. of extinct species.* But these results are not so inconsistent as they at first appear, because all the abundant species (except *Buccinum semistriatum*, already mentioned as the only extinct shell out of 100 found in the ancient tuffs of Somma) are now living in the neighbouring sea, whereas nearly all the lost species are so exceedingly rare that sometimes single individuals of them have alone been found. Nevertheless I regard the most ancient part of Etna as somewhat older than the foundations of Vesuvius, and if I were asked what relation the tertiary strata near Catania bear in point of age to our British formations, I should answer that they are about the age of the Norwich crag. In reference therefore to the Glacial Period I consider the oldest eruptions of Etna as of older date than the era of greatest cold in central and northern Europe.

The reader must not suppose that the marine strata with the associated basaltic rocks were first formed and then raised to their present height above the level of the sea, and that the great subaërial cone of Etna was a superstructure of later date; for there is reason to believe that a general and gradual upheaval of the foundations of Etna, together with the neighbouring country, was always going on during the long period of supra-marine eruptions. And this slow upward movement is probably still continuing, since raised beaches of sands with littoral shells of living species often retaining their colour are observed at the eastern base of Etna skirting the shore, and there are also lines of inland cliff cut in the tertiary strata and in the volcanic tuffs bearing witness to successive alterations in the relative level of sea and land.

Fossil plants of living species in ancient tuffs of Etna.—We

* See 'Mode of Origin of Mount Etna,' by the Author, Phil. Trans. Part II. for 1858, p. 778.

Plate V.

VIEW LOOKING UP THE VAL DEL BOVE, ETNA.

have rarely an opportunity of determining the exact nature of the vegetation which covered the mountain when some of the oldest showers of volcanic ashes were poured out; but there are some stratified tuffs at Fasano near Catania replete with fossil leaves which throw some light on this subject. I obtained several species of land-plants from these tuffs which were determined by Professor Heer to belong to species now living in Sicily. Among others were the sweet bay, *Laurus nobilis*, the common myrtle, *Myrtus communis*, and the Mastick tree, *Pistachia lentiscus*.

Val del Bove on the eastern flank of Etna.—Etna, when viewed whether from the north or south, is of a very symmetrical form, but on its eastern side it is intersected by a deep valley called the Val del Bove, the head or upper part of which is bounded by a precipice between 3,000 and 4,000 feet high, which begins immediately below the eastern margin of that highest platform which was before mentioned (p. 3) as having been produced by the truncation of the great cone. The annexed view, Plate V., taken from a drawing which I made in November 1828, will give the reader some idea of this precipice below the Platform No. 2, which was at that time covered with snow.

The great lava currents of 1811 and 1819 are seen pouring down from the higher parts of the Val del Bove, overrunning the forests of the great valley, and rising up in the foreground on the left with a rugged surface, on which many hillocks and depressions appear, such as often characterise a lava current before it has ceased to flow as well as after its consolidation.

The small cone, No. 7, was formed in 1811, and was still smoking when I saw it in 1828. The other small volcano to the left, from which vapour is issuing, was, I believe, one of those formed in 1819.

The following are the names of some of the points indicated in the sketch:—

1. Montagnuola.
2. Torre del Filosofo.
3. Highest cone.
4. Lepra.
5. Finocchio.
6. Capra.
7. Cone of 1811.
8. Cima del Asino.
9. Musara.
10. Zoccolaro.
11. Rocca di Calanna.

Description of Plate VI.—The second view (Pl. VI.) represents the same valley as seen from above, or looking directly from the Val del Bove, from the summit of the principal crater formed in 1819.*

The circular form of the Val del Bove is well shown in this view (Pl. VI.). To the right and left are the lofty precipices which form the southern and northern sides of the great valley, and which are intersected by dikes projecting in the manner afterwards to be described. In the distance appears the 'fertile region' of Etna, extending like a great plain along the sea-coast.

The spots particularly referred to in the plate are the following:—

a. Cape Spartivento, in Italy, of which the outline is seen in the distance.

b. The promontory of Taormino, on the Sicilian coast.

c. The river Alcantra.

d. The small village of Riposto.

e. Valley of Calanna.

f. The town of Aci Reale.

g. Cyclopean islands, or 'Faraglioni,' in the Bay of Trezza.

h. The great harbour of Syracuse.

i. The city of Catania, near which is marked the course of the lava which flowed from the Monti Rossi in 1669, and destroyed part of the city.

k. The Lake of Lentini.

l. To the left of the view is the crater of 1811, which is also shown at No. 7, in Plate V.

m. Rock of Musara also seen at No. 9, in Plate V.

The Val del Bove is of truly magnificent dimensions, a vast amphitheatre 4 or 5 miles in diameter, surrounded by nearly vertical precipices, the loftiest being at the upper or eastern end, where, as before stated, they are between 3,000 and 4,000 feet high, and the others on the north and south side diminishing gradually from that height to 500 feet as they extend eastward. The feature which first strikes the geelogist as distinguishing the boundary cliffs of this valley, is the prodigious multitude of vertical dikes which are seen in all directions traversing the volcanic beds. The circular form of the great chasm, and the occurrence of so many dikes, amounting perhaps to several thousands in number, cannot fail to recall to the mind of everyone familiar with Vesuvius the phenomena of the Atrio del Cavallo, although

* This view is taken from a sketch made by Mr. James Bridges, corrected after comparison with several sketches of my own. I am unable to point out the precise spot which this crater would occupy in the view represented in Plate V.; but I conceive that it would appear in the face of the great precipice, near which the smoke issuing from the cone No. 7 is made to terminate. There are many ledges of rock on the face of that precipice where eruptions have occurred.

Plate VI.

VIEW OF THE VAL DEL BOVE, ETNA, AS SEEN FROM ABOVE, OR FROM THE CRATER OF 1819.

the Val del Bove is on a scale as far exceeding that of Somma as Etna surpasses Vesuvius in magnitude.

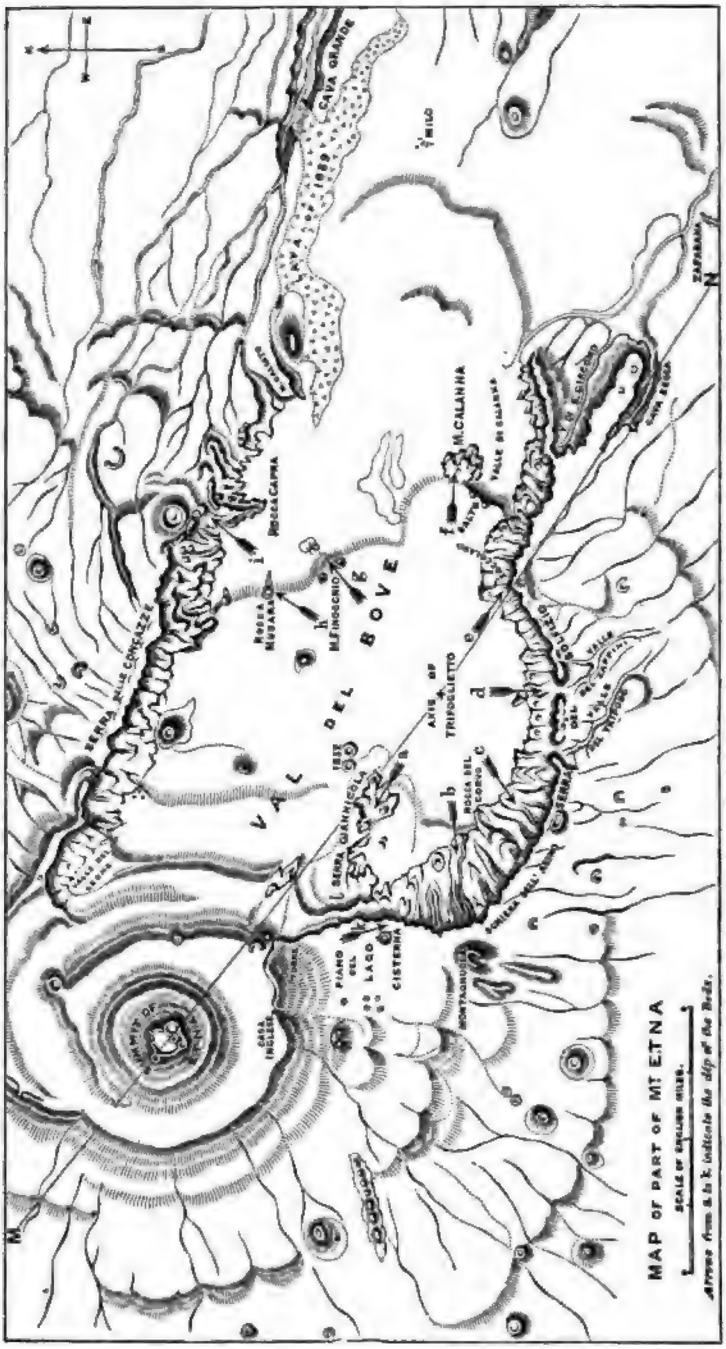
Internal structure of the mountain and proofs of a double axis of eruption.—When I first examined Etna in 1828, I supposed that the boundary walls of the great amphitheatre displayed such an arrangement of the beds as showed that the structure of that part of the mountain was very different from that which the escarpment of Somma exhibits. I imagined that the sloping away of the strata from a central axis to all points of the compass, or what has been called the quaquaversal dip, was wanting in the Val del Bove. But when I revisited the same district in 1857–8,* I discovered that the lower portion of the volcanic beds exposed to view in the great precipices *k*, *i*, at the head of the valley *h*, *i*, *k*, of the section fig. 78, page 12, dipped steeply to the west, and this arrangement of the strata, together with that observed in the other cliffs bounding the valley, can only be explained by assuming that there was once a great centre of eruption at or near the point in the annexed map (fig. 77, p. 10) which I have marked with a cross as indicating the axis of Trifoglietto. The direction of the arrows *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, indicate the various points of the compass towards which the strata have been observed to be inclined. I was accompanied in 1857 by Signor G. G. Gemmellaro, when we made out this quaquaversal dip, and came to the opinion that the point marked with a cross or the axis of Trifoglietto had been an ancient centre of eruption.†

In confirmation of this theory, Baron S. von Waltershausen has observed that there is an ancient set of greenstone dikes, thirteen or more in number, which radiate from the point or axis alluded to and are seen traversing the surrounding precipices. These greenstone dikes are distinguishable by their mineral composition from those of more modern doleritic lava which radiate from the present great centre of eruption or the summit of Etna. This centre may be called, from the modern name of the mountain, the axis of Mongi-

* See Paper on Mount Etna by the Author. Phil. Trans. Part II. for 1858.

† I was not then aware that Baron S. von Waltershausen had previously come to the same conclusion; for that part of his Atlas in which he announced this opinion was not published till after my return to England.

Fig. 77.


MAP OF PART OF MT ETNA
VAL DEL BOVE
LAVA OF 1689
CAVA GRANDE
M. CALANNA
ZAFFARANA
ROCCA CAPRA
SERRA GIANNICOLA
AXIS OF TRIFOGLIETTO
PIANO DEL LAGO
CISTERNA
MONTAGNUOLA
CASA INGLESE

Description of Fig. 77.—(Map of Etna, p. 10.)

Ground plan of the Val del Bove showing the dip of the beds on opposite sides of the axis of Trifoglietto.

Arrows *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, showing the dip of the beds in opposite directions from the centre of eruption or axis of Trifoglietto.

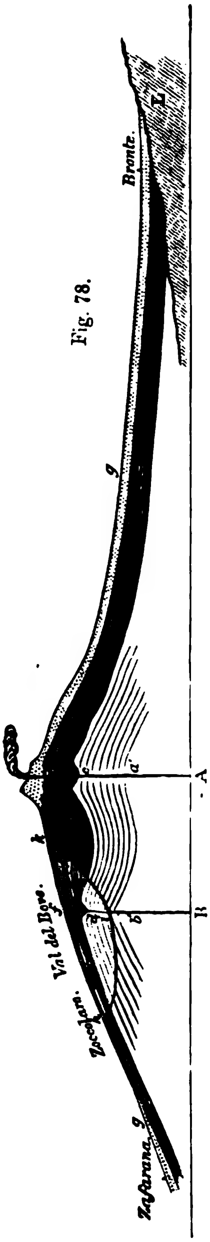
k. Arrow showing the direction of the dip of the beds in the Cisterna (see also *k* in the section fig. 78), where they are inclined 6° south-east, whereas the beds in the lower parts of the same precipice as indicated by the arrow *b*, dip in quite a different direction, or at an angle of more than 20° to the west.

l. Horizontal beds in the great precipice above the Serra Giannicola, resting on beds of trachyte and trachytic tuff and conglomerate, which last dip at angles of from 20° to 28° N.W. as indicated by the arrow *a*.

M. N. Line of section of fig. 78.

bello. In 1858, when I paid a third visit to the Val del Bove, I found that there was a great thickness of beds (*l*, of Map fig. 77), in that part of the precipice between the Piano del Lago and Giannicola, which are horizontal—a fact perfectly reconcilable with the theory that the structure of Mount Etna is due to its having been formed by the pouring out of lava and scoriæ from two great distinct centres of eruption before alluded to, viz., that of Trifoglietto and that of Mongibello; the latter having eventually obtained such an ascendency as to overwhelm the products of the former, and reduce the whole mountain to one symmetrical cone, broken subsequently by the great chasm of the Val del Bove on its eastern side, above described, a chasm of comparatively modern date. The accompanying section, p. 12, will explain the theory of the structure of Etna above alluded to, namely the hypothesis of a double axis by which all the dips in opposite directions in the Val del Bove, apparently so complicated, together with the horizontality of the beds immediately below the edge of the Piano del Lago, are found to be resolvable into a very simple arrangement, such as is exemplified in not a few of the great Javanese volcanos described by Junghuhn. That author has particularly called attention to the fact, that when there are two centres of eruption in the same volcanic mountain, there is a certain area between them, which he calls a saddle, where the beds of lava, or the showers of ashes, are level or horizontal. Among other instances he alludes to a saddle connecting the twin cones of Gede and Panggerango which is 7,870 feet high. The largest of the two cones, although truncated like Etna, is 9,226 feet high, and the lesser cone has a deep valley on one

Fig. 78.



Ideal section of Mount Etna, from West 20° N. to East 20° S., to illustrate the theory of a double axis of eruption. See M. N. Map, Fig. 77.

A. Axis of Mongibello.
B. Axis of Trifoglietto.
d, *c*, *b'*, *i*, *d*. Older lavas, chiefly trachytic.
c, *c*, and *d*, *f*. Lavas chiefly doleritic, poured out from A after the axis or focus B was spent, and before the origin of the Val del Bove.
g g. Scoriæ and lavas of later date than the Val del Bove.

h, *i*, *k*. Val del Bove. The faint lines represent the missing rocks.
N.B. In the section between *i* and *k*, it will be seen that the beds at the base, or near *i*, dip steeply away from the Val del Bove; those in the middle, or below *k*, are horizontal, and those at top, or at *k*, dip gently towards the Val del Bove (see pp. 9 and 13).
L. Older tertiary and sandy rocks, chiefly sandstones.

side comparable to the Val del Bove. In the case of Etna we are unable to decide which of the two foci, A or B, fig. 78, gave vent to the earliest eruptions, but it is clear that after B (or the focus of Trifoglietto) was spent, the main vent of Mongibello continued in full vigour, and overwhelmed with its lavas and scoriæ the minor cone *d*, *i*, until it reduced the whole to one slope *k*, *f*, *h*. Subsequently the chasm called the Val del Bove, *h i k*, was formed, chiefly I presume by explosions similar to those which are supposed, in Vol. I. p. 631, to have removed the old central portion of Somma before the modern cone of Vesuvius was built up.

The arrangement of the beds seen between *k* and *i*, fig. 78, in the great precipice at the head of the Val del Bove, is of peculiar geological interest, more especially the horizontality of those beds of lava which are shaded with a dark tint immediately below *k*. In the entire absence of dip which they exhibit, they are strikingly contrasted with lower beds seen in

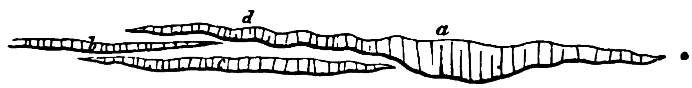
the same section in the Serra Giannicola, which are highly inclined. In order to study the horizontal beds, I made two descents of the great precipice at different points previously examined by very few geologists, and observed a remarkable resemblance of one of the old lava currents with the lava of 1669, which overflowed some level ground in the neighbourhood of Catania, where there had been a rich vegetation. The vegetable soil was there turned or burnt into a layer of red-brick-coloured stone, reminding me of the red bands which separate so many of the lavas in Madeira. Midway between the top and bottom of the great precipice, at a place called Teatro Grande, the ancient lava current is seen, which had evidently cooled on a flat surface, and the lower scoriaceous part of which reposed on a red band of burnt soil, over which it had poured. Overlying the bottom scoriæ was a central mass of stony lava no less than *forty feet* thick, divided by vertical rents, so as to be almost columnar, and above this again was the usual upper scoriaceous and highly vesicular division of the current. No hypothesis, except that of the double axis, can give even a plausible explanation of the position of this powerful current, which must have cooled on a flat surface. But the phenomena are quite reconcilable with the former existence at this point of a saddle between the cones.

When treating of Vesuvius, in the first volume, p. 634 I gave the reader an account of the theory of elevation craters as it has been called, to which some geologists have attributed the high inclination of the lavas of Somma, which dip outwards in all directions from a central axis. The structure of Mount Etna has been referred by partisans of the same school to a similar movement of upheaval, which caused all the volcanic formations previously horizontal to be suddenly uplifted into a mountain mass, so as to assume a conical form, the beds of lava and scoriæ being made to dip away in all directions from the axis of upheaval. Even if it were true that the alternate scoriaceous and stony beds exhibited a quaquaversal dip, many unanswerable objections might be offered to the above-mentioned hypothesis. Among others, I may mention the impossibility of imagining that so large

a proportion of the dikes of different ages should be so nearly vertical as they are found to be. But as I have dwelt so long on this subject on a former occasion, I will merely say here, in favour of the theory of eruption as opposed to that of upheaval, that one cone formed by eruption may and often does embrace and bury a contiguous cone of older date and of similar origin; whereas a cone of upheaval, even if we grant that the volcanic forces ever give rise to such a structure, cannot be conceived to envelope an older cone.

Want of parallelism in the ancient lavas.—It will be useful, however, to point out in detail some features in the shape

Fig. 79.

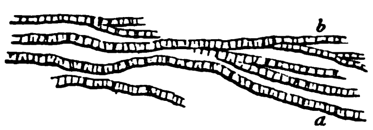


Stony layers in the northern escarpment of the Val del Bove in the Serra di Cerrita, part of the Concazze (see Map, fig. 77), where the *precipice* is 1,000 feet high.

a. Vertical section of rock 40 feet.
b, c. Beds to the westward in the same plane as the thickest part of *a.*
d. Same bed as *a* thinning out westward to a thickness of 4 or 5 feet at a distance of a few hundred yards from *a.*

and structure of the beds which are intersected in the cliffs of the Val del Bove, in order to show that they are not uniform in thickness, and that they by no means preserve everywhere that perfect parallelism to each other which has been ascribed to them. They present, it is true, to the eye, a great appearance of regularity when viewed as a whole and from a distance, but when more closely inspected, they are found to be variable, both in thickness and in their dip, as much so as we have any right to expect in currents which have flowed down the sides of a steeply sloping cone like Etna from some opening at or near the summit. The annexed diagrams will explain the appearance of the lavas and scoriæ at many points in the north and south walls of the Val del Bove, where they are laid open to view in vertical sections.

Fig. 80.

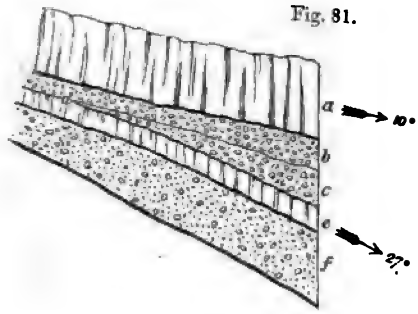


Non-parallel beds of stony lava in the Concazze, or part of the northern escarpment of the Val del Bove.

Vertical distance from *a* to *b* about 60 feet. Incoherent tuffs and scoriæ intervene between the solid beds here figured.

As the continuity of many of the beds in the boundary cliffs of the Val del Bove has been thought by some to be opposed to the theory of their having flowed in succession one over the other down the sloping sides of a great cone, I may remark, that provided we behold a section running in the same direction as the original course of the currents, we have every reason to expect them to be continuous for several miles. As to their dip, even if it amount to 20° or 30°, there is no reason for concluding, as I shall show in the sequel, that they may not have been originally inclined at such high angles.

Fig. 81.

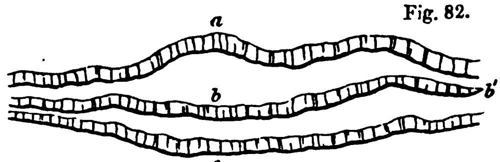


Beds of doleritic lava and scoriæ in the Serra del Solfizio, south side of the Val del Bove.

a. Bed of stony lava 12 feet thick, inclined at an angle of 10°.
b. Bed of scoriæ with angular fragments of scoriaceous lava 5 feet thick.
c. Bed of similar materials, but coarser, thinning out at *d*.
e. Bed of basaltic lava, 3 feet in its greatest thickness, and dipping at an angle of 27° (or 17° steeper than *a*).
f. Fragmentary scoriaceous bed 10 feet thick, having a similar dip with many others which underlie it.

I may here remark, that I saw no signs of buried lateral cones laid open by the grand sections exhibited in the cliffs of the Val del Bove. Such buried cones are distinctly to be seen in some inland ravines and in seacliffs in Madeira, and their absence in the Val del Bove implies that the great period of lateral eruptions was subsequent in date to the origin of that valley.

Fig. 82.

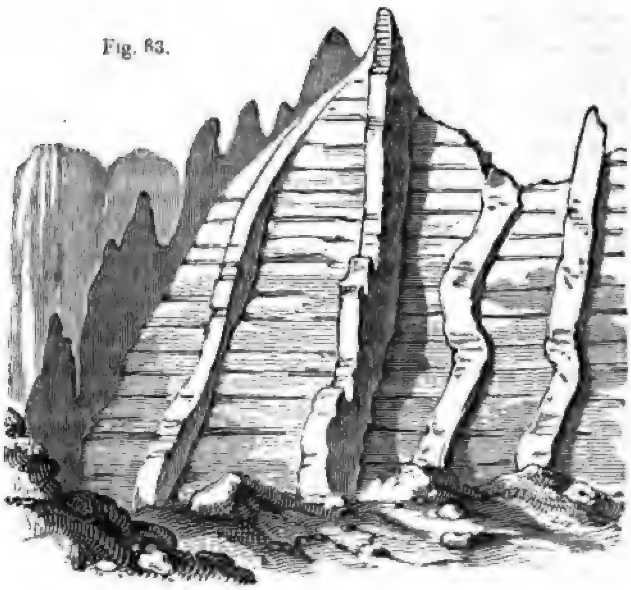


Curvatures of lava in the hill of Zoccolaro, at the eastern extremity of the Serra del Solfizio.

a, *b*, *c*. Three beds of lava varying in thickness from 4 to 6 feet, and separated by incoherent matter.
b thins out at *b'*.
a and *c* are 40 feet apart in the middle of this section, and come within 12 and 14 feet of each other at the two extremities of the same.

Dikes in the Val del Bove.—I have already alluded to a set of dikes of greenstone or diorite, observed by Waltershausen to converge in the supposed centre of eruption or axis of Trifoglietto (see p. 11). A much greater number of dikes or vertical walls of lava radiate from the modern centre of eruption, or that of Mongibello. They consist chiefly of dolerite or greystone, intermediate between trachyte and basalt,—the trachi-dolerites of some geologists. They vary

Fig. 83.



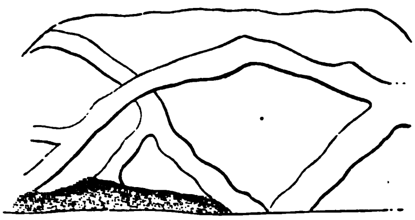
Dikes at the base of the Serra del Solfizio, Etna.

in breadth from 2 to 20 feet and upwards, and usually project from the face of the cliffs, as represented in the annexed drawing (fig. 83). They consist of harder materials than the strata which they traverse, and therefore waste away less rapidly under the influence of that repeated congelation and thawing to which the rocks in this zone of Etna are exposed. The dikes are, for the most part, vertical, but sometimes they run in a tortuous course through the tuffs and breccias, as represented in fig. 84.

The dikes are most numerous near the head of the Val del

Bove, or near the two ancient centres of eruption before alluded to as the axes of Trifoglietto and Mongibello. They continue to abound throughout that zone of the mountain where lateral eruptions are frequent, but below that level they become extremely rare, as in the valley of Calanna, for example, in which the section of the Val del Bove is continued. Still lower in the same easterly direction, as in the valley of San Giacomo for example, none occur. The rarity or absence of dikes as we recede from the great centres of eruption, is precisely what we might have expected if the vertical fissures now filled with solid rock were once the channels which gave passage to lava currents. Some of the dikes blend at their termination upwards with currents of lava, so that they stop short in their vertical direction, and do not cut through the higher currents of lava which were of a date posterior to the dikes.

Fig. 84.



Tortuous veins of lava at Punto di Giumento.

We know not how large a quantity of modern lava may have been poured into the bottom of the Val del Bove, yet we perceive that eruptions breaking forth near the centre of Etna have already made no small progress in filling up this great hollow. Even within the memory of persons now living, the rocks of Musara and Capra have, as before stated, lost much of their height and picturesque grandeur by the piling up of recent lavas round their base, and the great chasm has intercepted many streams which would otherwise have deluged the fertile region below. The volcanic forces are now labouring, therefore, to repair the breach caused probably by one or more paroxysmal eruptions of ancient date on one side of the great cone; and unless their energy should decline, or a new sinking take place, they may in time efface this inequality. In that event, the restored portion will always be unconformable to the more ancient part, yet it will consist, like it, of alternating beds of lava and scoriæ,

which, with all their irregularities, will have a general slope from the centre and summit of Etna towards the sea.

Origin of the Val del Bove.—It will be seen by the ideal section given in fig. 78, p. 12, that I suppose the modern centre of eruption A (that of Mongibello), to have overwhelmed the ancient lateral cone formed by B, so as to reduce the whole mountain to a symmetrical form, the present valley *k, i, h* having then no existence. In what manner this enormous gulf was formed has been a fertile subject of conjecture. So late as the year 1822, as we shall see in the next chapter, during a violent earthquake and volcanic eruption in Java, one side of the mountain called Galongoon, which was covered by a dense forest, became an enormous gulf in the form of a semicircle. The new cavity was about midway between the summit and the plain, and surrounded by steep rocks.

It will be shown that in that instance vast quantities of boiling water and mud were thrown up like a waterspout, and great blocks of basalt were projected to a distance of 7 miles, and ashes and lapilli of the size of nuts as far as 40 miles. Numerous villages 24 miles distant from the centre of eruption were completely buried, implying that the solid matter ejected by the explosive power of steam was voluminous enough to account for the formation of the new cavity, vast as were its dimensions.

It will be also seen in the thirtieth chapter, that in the year 1772, Papandayang, the largest volcano in the island of Java, lost 4,000 feet of its height, at the same time that 40 villages, spread over an area 14 miles in length and 6 in breadth, were destroyed. According to the earlier accounts they were engulphed, and the truncation of the cone was attributed to subsidence; but the subsequent investigations of Junghuhn about seventy years after the explosion have shown that the villages were overwhelmed by volcanic sand and scoriæ, under which they now lie buried; and it cannot be doubted that the loss of height of the great cone, attributed to subsidence, was caused in great part at least by explosion. The summit of Carguairazo, one of the loftiest of the Andes of Quito, is said to have 'fallen in' on July 19, 1698, and

another cone of still greater altitude in the same chain, called Capac Urcu, was, according to tradition, truncated a short time before the conquest of America by the Spaniards. It is possible that when the lava is rising to the summit of such cones the foundations of parts of the volcanic structure may be undermined and melted, so that one part after another of the walls of the highest crater may sink down before the principal escape of gas and the ejection of scoriæ take place.

In the year 1792 a small circular tract called the Cisterna (see Map, fig. 77, p. 10), situated on the edge of the platform from which the highest cone of Etna rises, sank down to the depth of about 40 feet, leaving a chasm on all sides of which a vertical section is now seen of alternating stony lavas and scoriæ. It is conceivable, therefore, that parts of the area of the Val del Bove may, in like manner, have fallen in during earthquakes; but I think it probable that by far the greater portion of the huge cavity was caused by explosions of pent-up vapours escaping from subterranean fissures, during one or more lateral eruptions connected perhaps with a temporary revival of the ancient focus of eruption which I have called the axis of Trifoglietto.

Eruptions of Etna of historical date.—Truncation of the great cone.—What I have hitherto said of the first existence of Etna as a submarine volcano, the building up of the subaërial part of the mountain by the pouring out of lava and scoriæ from two principal centres, the accompanying general upheaval of the whole mass above the level of the sea, and the probable origin of the Val del Bove, has been entirely founded on geological inferences from the internal structure of the mountain.

We may next turn to history and enquire what changes are recorded to have taken place since the volcano was an object of interest to the civilised world.

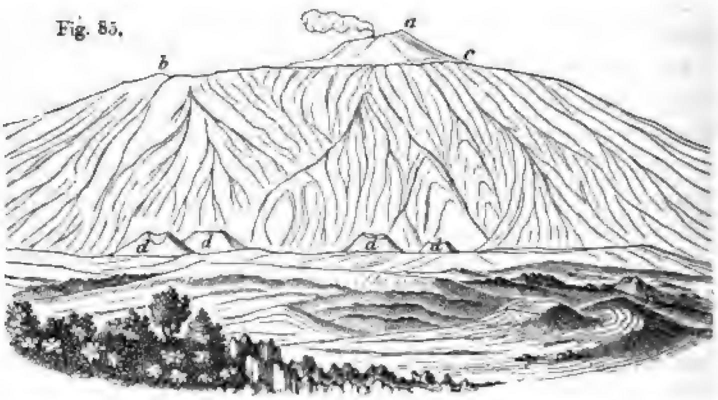
Etna appears to have been in activity from the earliest times of tradition; for Diodorus Siculus mentions an eruption which caused a district to be deserted by the Sicani before the Trojan war. Thucydides informs us, that in the sixth year of the Peloponnesian war, or in the spring of the year 425 B.C., a lava stream ravaged the environs of Catania, and

this he says was the third eruption which had happened in Sicily since the colonisation of that island by the Greeks.* The second of the three eruptions alluded to by the historian took place in the year 475 B.C., and was that so poetically described by Pindar, two years afterwards, in his first Pythian ode:—

κιων
Δ' δυρανια συνεχει
Νιφοεσσ' Αἶτνα, πανετες
Χιονος ὀξειας τιθηνα.

In these and the seven verses which follow, a graphic description is given of Etna, such as it appeared five centuries

Fig. 85.



Truncated appearance of the summit of Etna on the north-west side, as seen from near Bronte.—From Sartorius von Waltershausen's Atlas, plate 2.

a. Modern cone. *b, c.* Margin of highest platform. *d.* Minor cones.

before the Christian era, and such as it has been seen when in eruption in modern times. The poet is only making a passing allusion to the Sicilian volcano, as the mountain under which Typhæus lay buried, yet by a few touches of his master hand every striking feature of the scene has been faithfully portrayed. We are told of 'the snowy Etna, the pillar of heaven—the nurse of everlasting frost, in whose deep caverns lie concealed the fountains of unapproachable fire—a stream of eddying smoke by day—a bright and ruddy flame

* Book iii., at the end.

by night; and burning rocks rolled down with loud uproar into the sea.'

Alessi in his history of Etna refers to Seneca, who, in the first century of our era, reminds Lucillius that Mount Etna had in his time lost so much of its height that it could be no longer seen by boatmen from certain points whence it had been previously visible. At a much later period, Falcando relates that the lofty summit of Etna had fallen in in 1179. and it was destroyed, according to Fazzello, for the third time in 1329. Again it was engulphed for the fourth time in 1444, and finally the whole top of the mountain fell in in 1669.* The result of these and previous truncations may well have produced the form of a truncated cone, represented in the accompanying drawing (fig. 85).

Eruption of 1669. *Monti Rossi formed.*—The great eruption last alluded to of 1669, deserves particular attention as the first noticed by scientific observers. An earthquake had levelled to the ground all the houses in Nicolosi, a town situated near the lower margin of the woody region, about 20 miles from the summit of Etna, and 10 from the sea at Catania. Two gulfs then opened near that town, from whence sand and scoriæ were thrown up in such quantity, that in the course of three or four months, a double cone was formed, called Monti Rossi (or Mônte Rosso) about 450 feet high. But the most extraordinary phenomenon occurred at the commencement of the convulsion in the plain of S. Lio. A fissure six feet broad, and of unknown depth, opened with a loud crash, and ran in a somewhat tortuous course to within a mile of the summit of Etna. Its direction was from north to south, and its length 12 miles. It emitted a most vivid light. Five other parallel fissures of considerable length afterwards opened one after the other, and emitted vapour, and gave out bellowing sounds which were heard at the distance of 40 miles. This case seems to present the geologist with an illustration of the manner in which those continuous dikes of vertical porphyry were formed, which are seen to traverse some of the older lavas of Etna; for the light emitted from the great rent of S. Lio

* Alessi, Storia critica dell' Eruz. dell' Etna, p. 149.

appears to indicate that the fissure was filled to a certain height with incandescent lava, probably to the height of an orifice not far from Monti Rossi, which at that time opened and poured out a lava current. When the melted matter in such a rent has cooled, it must become a solid wall or dike, intersecting the older rocks of which the mountain is composed; similar rents have been observed during subsequent eruptions, as in 1832, when they radiated in various directions from the centre of the volcano. It has been remarked by M. Elie de Beaumont, that such star-shaped fractures may indicate a slight upheaval of the whole of Etna. They may

Fig. 86.

Minor cones on the flanks of Etna.

1. Monti Rossi, near Nicolosi, formed in 1669. 2. Monpileri.

be the signs of the stretching of the mass, when it was being raised gradually by a force from below.*

The lava current of 1669, before alluded to, soon reached in its course a minor cone called Monpileri, at the base of which it entered a subterranean grotto, communicating with a suite of those caverns which are so common in the lavas of Etna. Here it appears to have melted down some of the vaulted foundations of the cone, so that the whole of that hill became slightly depressed and traversed by numerous open fissures.

Part of Catania destroyed.—The lava, after overflowing fourteen towns and villages, some having a population of

* Mém. pour servir, &c., tom. iv. p. 116.

between 3,000 and 4,000 inhabitants, arrived at length at the walls of Catania. These had been purposely raised to protect the city; but the burning flood accumulated till it rose to the top of the rampart, which was 60 feet in height, and then it fell in a fiery cascade and overwhelmed part of the city. The wall, however, was not thrown down, but was discovered long afterwards, by excavations made in the rock by the Prince of Biscari; so that the traveller may now see the solid lava curling over the top of the rampart, as if still in the very act of falling.

This great current performed the first 13 miles of its course in 20 days, or at the rate of 162 feet per hour, but required 23 days for the last two miles, giving a velocity of only 22 feet per hour; and we learn from Dolomieu that the stream moved during part of its course at the rate of 1,500 feet an hour, and in others took several days to cover a few yards.* When it entered the sea it was still 600 yards broad, and 40 feet deep. It covered some territories in the environs of Catania, which had never before been visited by the lavas of Etna. While moving on, its surface was in general a mass of solid rock; and its mode of advancing, as is usual with lava streams, was by the occasional fissuring of the solid walls. A gentleman of Catania, named Pappalardo, desiring to secure the city from the approach of the threatening torrent, went out with a party of 50 men whom he had dressed in skins to protect them from the heat, and armed with iron crows and hooks. They broke open one of the solid walls which flanked the current near Belpasso, and immediately forth issued a rivulet of melted matter which took the direction of Paternó; but the inhabitants of that town, being alarmed for their safety, took up arms and put a stop to further operations.†

As another illustration of the solidity of the walls of an advancing lava stream, I may mention an adventure related by Recupero, who, in 1766, had ascended a small hill formed of ancient volcanic matter, to behold the slow and gradual

* See Prof. J. D. Forbes, Phil. Trans., 1846, p. 155, on Velocity of Lava.

† Ferrara, Descriz. della Etna, p. 108.

approach of a fiery current, 2½ miles broad; when suddenly two small threads of liquid matter issuing from a crevice detached themselves from the main stream, and ran rapidly towards the hill. He and his guide had just time to escape when they saw the hill, which was 50 feet in height, surrounded, and in a quarter of an hour melted down into the burning mass, so as to flow on with it.

But it must not be supposed that this complete fusion of rocky matter coming in contact with lava is of universal, or even common occurrence. It probably happens when fresh portions of incandescent matter come successively in contact with fusible materials. In many of the dikes which intersect the tuffs and lavas of Etna, there is scarcely any perceptible alteration effected by heat on the edges of the horizontal beds, in contact with the vertical and more crystalline mass. On the site of Monpileri, one of the towns overflowed in the great eruption above described, an excavation was made in 1704; and by immense labour the workmen reached, at the depth of 35 feet, the gate of the principal church, where there were three statues, held in high veneration. One of these, together with a bell, some money, and other articles, were extracted in a good state of preservation from beneath a great arch formed by the lava. It seems very extraordinary that any works of art, not encased with tuff, like those in Herculaneum, should have escaped fusion in hollow spaces left open in this lava current, which was so hot at Catania eight years after it had entered the town, that it was impossible to hold the hand in some of the crevices.

Subterranean caverns on Etna.—Mention was made of the entrance of a lava stream into a subterranean grotto, whereby the foundations of a hill were partly undermined. Such underground passages are among the most curious features on Etna, and may perhaps be caused by the sudden conversion into steam of lakes or streams of water overwhelmed by a fiery current. Great volumes of vapour thus produced may force their way through liquid lava already coated over externally with a solid crust, and may cause the sides of such passages as they harden to assume a very irregular outline. Near Nicolosi, not far from Monti Rossi, one of

these great openings may be seen, called the Fossa della Palomba, 625 feet in circumference at its mouth, and 78 deep. After reaching the bottom of this, we enter another dark cavity, and then others in succession, sometimes descending precipices by means of ladders. At length the vaults terminate in a great gallery 90 feet long, and from 15 to 50 broad, beyond which there is still a passage, never yet explored; so that the extent of these caverns remains unknown. The walls and roofs of these great vaults are composed of rough bristling scoriæ, of the most fantastic forms.

Changes produced by modern eruptions in the Val del Bove.— The change which had taken place in the aspect of several parts of Etna, but especially in the Val del Bove, between my first and second visits, or between 1825 and 1857, was very striking. That deep chasm is called in the provincial dialect of the peasants, 'Val di Bué,' for here the herdsman

——in reductâ valle *mugientium*
Prospectat errantes greges.

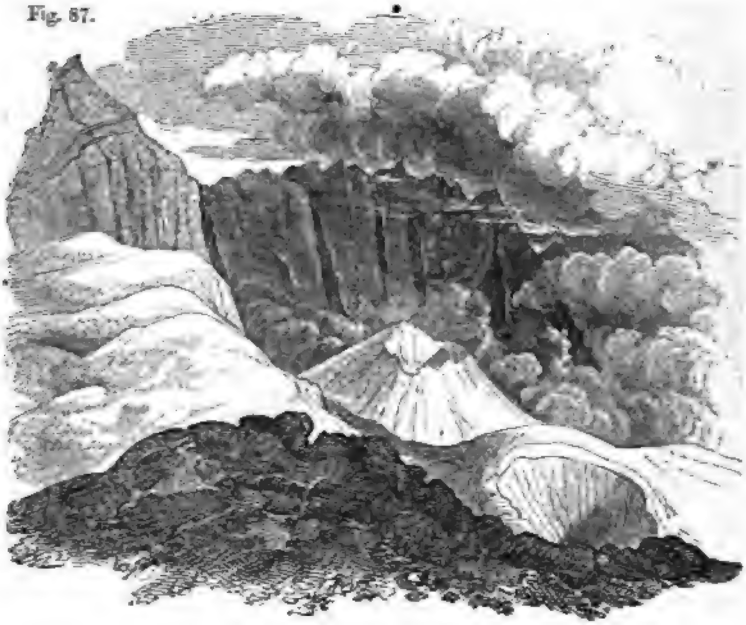
Dr. Buckland was, I believe, the first English geologist who examined this valley with attention, and I am indebted to him for having described it to me, before I visited Sicily, as more worthy of attention than any single spot in that island, or perhaps in Europe.

The views, Plates V. and VI. above described, p. 7, have already given the reader some idea of the scenery, looking up and down the vast amphitheatre, which is between 4 and 5 miles in diameter. The accompanying view, fig. 87, is part of a panoramic sketch, which I made from the summit of the highest cone on December 1, 1828. Every part of the mountain was then free from clouds, except the Val del Bove, some of the upper precipices of which, alone, were visible with their large vertical and projecting dikes as seen in the drawing. The crater nearest the foreground and the small cone adjoining, were among those which had been thrown up during the eruptions of 1810 and 1811, or eighteen years before my visit.

The lavas which were poured out from near the head of the Val del Bove in these years, and subsequently in 1819,

flowed between some isolated rocks, called Finocchio, Capra, and Musara, which are remnants of the old cone of Etna, not destroyed at the time when the Val del Bove was formed. The position of these is pointed out at numbers 5, 6, and 9, in Plate V. Their height had already been much reduced by the flowing round them of the currents of 1811 and 1819, and in 1857 I found that the lavas of 1852 had still farther diminished their importance. When I first saw them as I

Fig. 87.



View from the summit of Etna into the Val del Bove.

ascended the valley, I compared them to the Trosachs in the Highlands of Scotland which

> Like giants stand
> To sentinel enchanted land;

though I remarked that the stern and severe grandeur of the scenery which they adorned, was not such as would be selected by a poet for a vale of 'enchantment.' The character of the scene would accord far better with Milton's picture of the infernal world; and if we imagine ourselves to behold in motion, in the darkness of the night, one of those fiery

currents which have so often traversed the great valley, we may well recall

> ——yon dreary plain, forlorn and wild,
> The seat of desolation, void of light,
> Save what the glimmering of these livid flames
> Casts pale and dreadful.

The strips of green herbage and forest land, which have here and there escaped the burning lavas, serve, by contrast, to heighten the desolation of the scene. When first I visited the valley, nine years after the eruption of 1819, I saw hundreds of trees, or rather the white skeletons of trees, on the borders of the black lava, the trunks and branches being

Fig. 88.

View of the rocks Finocchio, Capra, and Musara, Val del Bove.

all leafless, and deprived of their bark by the scorching heat emitted from the melted rock; an image recalling those beautiful lines:—

> As when heaven's fire
> Hath scath'd the forest oaks, or mountain pines,
> With singed top their stately growth, though bare,
> Stands on the blasted heath.

An unusual silence prevails throughout this region; for there are no torrents dashing from the rocks, nor any movement of running water in this valley, such as may almost invariably be heard in mountainous regions. Every drop of water that falls from the heavens, or flows from the melting

ice and snow, is instantly absorbed by the porous lava; and such is the dearth of springs, that the herdsman is compelled to supply his flocks, during the hot season, from stores of snow laid up in hollows of the mountain during winter.

Late in the autumn, when the sun is shining, both on the higher and lower parts of Etna, and on every other part of Sicily, clouds of fleecy vapour often fill the Val del Bove, and are sometimes partially dispersed along the face of the lofty precipices, causing the black outlines of the dikes to stand out in picturesque relief. About midday, when the vapours begin to rise, the changes of scene are varied in the highest degree, different rocks being unveiled and hidden by turns, and the summit of Etna often breaking through the clouds for a moment with its dazzling snows, and being then as suddenly withdrawn from the view.

Eruptions of 1811 *and* 1819.—I have alluded to the streams of lava which were poured forth in 1811 and 1819. Gemmellaro, who witnessed these eruptions, informs us that the great crater in 1811 first testified by its loud detonations, that a column of lava had ascended to near the summit of the mountain. A violent shock was then felt, and a stream broke out from the side of the cone, at no great distance from its apex. Shortly after this had ceased to flow, a second stream burst forth at another opening, considerably below the first; then a third still lower, and so on till seven different issues had been thus successively formed, all lying upon the same straight line. It has been supposed that this line was a perpendicular rent in the internal framework of the mountain, which rent was probably not produced at one shock, but prolonged successively downwards, by the weight, pressure, and intense heat of the internal column of lava, as its surface subsided by gradual discharge through each vent.*

In 1819 three large mouths or caverns opened very near those which were formed in the eruptions of 1811, from which flames, red-hot cinders, and sand were thrown up with loud explosions. A few minutes afterwards another mouth opened below, from which flames and smoke issued; and

* Scrope on Volcanos, 1st ed. p. 160.

finally a fifth, lower still, whence a torrent of lava flowed, which spread itself with great velocity over the Val del Bove. When it arrived at the precipice called the Salto della Giumenta at the head of the valley of Calanna, it poured over in a cascade, and made an inconceivable crash as it was dashed against the bottom. So immense was the column of dust it raised by the abrasion of the tufaceous hill over which the hardened mass descended, that the Catanians were in great alarm, supposing a new eruption to have burst out in the woody region, exceeding in violence that near the summit of Etna.

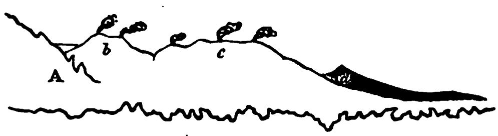
Mr. Scrope observed this current in the year 1819, slowly advancing down a considerable slope, at the rate of about a yard an hour, nine months after its emission. The lower stratum being arrested by the resistance of the ground, the upper or central part gradually protruded itself, and, being unsupported, fell down. This in its turn was covered by a mass of more liquid lava, which swelled over it from above. The current had all the appearance of a huge heap of rough and large cinders rolling over and over upon itself by the effect of an extremely slow propulsion from behind. The contraction of the crust as it solidified, and the friction of the scoriform cakes against one another, produced a crackling sound. Within the crevices a dull red heat might be seen by night, and vapour issuing in considerable quantity was visible by day.*

Eruption of August 1852.—Of all the recorded eruptions of Etna, with the exception of that of 1669 already mentioned, that which began in August 1852 and continued till May of the following year, was the most remarkable for the volume of lava which was poured out. In the annexed woodcut, fig. 89, I have given the outline of the two cones (marked 1852 in the Map, p. 10) from which in that year the lava issued, and in fig. 90 the course of the great stream is pointed out as it flowed from those cones *b*, *c*, through the Val del Bove, and beyond to Milo in one direction, or to the left, and to Zafarana on the right. Scoriæ were thrown up from the largest of the two cones *c*, which was formed together with *b*

* Scrope on Volcanos, 1st ed., p. 102.

at the base of the great precipice at the head of the Val del Bove. At the end of 16 days the cone *c* was about 500 feet high on its eastern side. So great was the expanse of molten matter that the whole valley when seen by Dr. Giuseppe Gemmellaro at the end of August was like a sea of fire. In September it reached the Salto della Giumenta before mentioned. In its descent over the precipice it sounded as if metallic and glassy substances were being broken. The lava streams *d d'*, which poured out till the latter part of November, were about 2 miles broad and 6 long. They continued to issue with some intermissions for more than nine months until May 1853. The depth of single streams was from 8 to 16 feet, but when

Fig. 89.



The two cones formed in the Val del Bove by the eruption of 1852.

A. Lower part of Giannicola Grande. *c.* Lower cone called Centenario.
b. Upper or western cone. *d.* Commencement of current of lava of 1852.

piled over one another they were from 30 to 50 feet thick, and at one point near the Portella or lower entrance of the valley of Calanna they seemed to me to have attained a thickness of 150 feet.

An unusual event, and one of no small geological interest, occurred some weeks after May 27th, when to all appearance the flowing of lava had entirely ceased, and when all the currents had become encrusted over with so firm a covering of scoriæ that the inhabitants could walk upon them with safety. Within a certain area six or seven hundred yards in diameter, and situated between Zafarana and Ballo, all the fruit-trees and vines were struck dead as if by lightning. The ground exhaled no hot gases, and the vegetation did not suffer in the space intervening between the parched-up area and the recent lava, which was only a few hundred yards distant. Dr. Giuseppe Gemmellaro has suggested, as the most natural explanation of the phenomenon, that the lava had gradually made its way through underground pas-

sages, until coming beneath the fields alluded to, it dried up the roots of the plants by its heat. It is well known (see above, p. 24) that vaults and tunnels abound in many of the modern lavas of Etna, and such empty spaces must sometimes at subsequent periods unavoidably become filled with fused matter, which may then solidify under considerable pressure, giving rise to masses of crystalline rock or sometimes perhaps to tortuous veins like those represented in fig. 84, p. 17, and offering a perplexing problem to a geologist who might obtain a section of them without having any clue to the peculiar conditions under which they originated.*

Fig. 90.

Course of the lava currents through the Val del Bove in 1852–3, as seen from above.

a. Part of Giannicola Grande.
b, c, d. Same as fig. 89.
e. Monte Finocchio Inferiore.
f. Rocca Musara.
g. Giannicola Piccola.
h, h. Concazze.
i. Serra del Solfizio.

In 1858 I found the surface of this lava of 1853 still giving out columns of white steam from numerous fumeroles especially after heavy rains. Near Zafarana its surface is divided into longitudinal ridges rising from 30 to 70 feet above the bottom of the intervening and parallel depressions.

It was a melancholy sight to behold pastures which I had seen verdant in 1828 in the valley of Calanna black and desolate, and the region above so deluged with the sterilising products of the late eruption that there had ceased to be a picturesque contrast between tracts of the old forest and dark strips of modern lava. The larger part of the great valley had become one monotonous desert no longer supporting any cattle, nothing to justify its original name, and with scarcely a living creature to be seen, though a few goats were

* Etna Paper, p. 22: see above, p. 9.

still driven up to browse on some shrubby knolls which had escaped the general devastation. After passing several days without seeing even a goat, the footmarks of a wolf imprinted at one point on some loose volcanic sand quite surprised me and made me enquire where they could still find any prey.

I crossed on foot a part of the new lava-field, in company with Signor G. G. Gemmellaro, to the rock called Finocchio, which in 1828 I had reached easily on mule-back. There was now no foot-path leading to it, and we found the black scoriaceous crust of the lava of 1852 bent into exceedingly sharp, longitudinal ridges, separated by narrow interspaces from 20 to 40 feet deep, the sides of each ridge sloping at angles of from 20° to 40°, but seeming at some points to be absolutely vertical. On the crests of each ridge were fragments of scoriform lava, sometimes tabular, and sticking up edgeways, like sheets of broken ice on a Canadian river, where an obstruction or 'jam' has stopped the floating masses. More frequently the projecting portions of the superficial crust assumed the forms of gigantic madrepores, or of various animals, such as dogs and deer, or still oftener the heads of elks with branching horns. The surface often resembled, in all but colour, the descriptions given of coral reefs; and at one moment when my foot slipped, I had an opportunity of knowing that the stony asperities could tear the flesh of my hands as readily as real corals. The stones on the top and sides of most of the ridges were so loose, that no sooner was one of them set a-rolling than it started a number of others, until a continuous avalanche poured down into the trough below; but as we had to zigzag our way up each steep ascent, there was little danger of one of us being just under his companion when the torrent came down. Now and then our direct march was arrested by a ridge, rendered impassable by its steepness or the incoherence of the stony fragments forming its crust, which obliged us to make a long circuit, often with our backs turned towards our goal, the hill of Finocchio. The manner in which detached blocks of various shapes and sizes were occasionally poised one upon another, on very narrow ridges, made us marvel that high winds had not blown them down. I climbed up to some of

them, to ascertain that they were not soldered on to the mass of scoriæ below; but I found them free to move and only holding on by the slight inequalities of their surface.

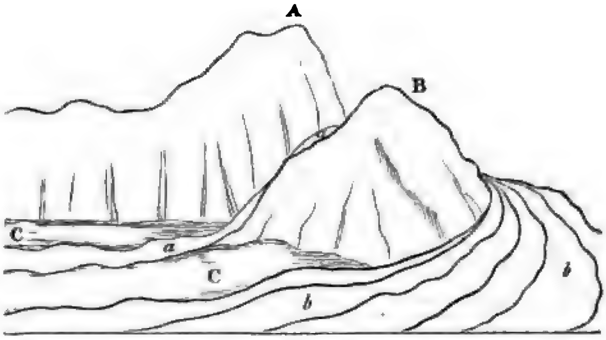
When at length we reached Finocchio we found it standing like a rocky islet submerged up to its middle in lavas of different ages, and with the fresh current of 1852 near its base. The relief afforded to the eye by that oasis was very great; and although the day was cloudy, the green turf enlivened by the flowers of a yellow ragwort, looked dazzling by contrast with the dark surrounding desert, and the autumnal crocus (*colchicum autumnale*), also in full bloom, seemed more than ever beautiful.

The manner in which pieces of loose scoriæ had often rolled down in great numbers from the ridges into the troughs of the lava serves to show to what an extent superficial inequalities may be reduced, or even effaced, when fresh currents overflow older ones. This may partly account for the regularity and parallelism of the successive stony lavas with their upper and under scoriæ in the escarpments of the Val del Bove; but the chief reason why those ancient currents are for the most part so conformable to each other is, I believe, the steepness of the slope down which they descended; the lofty and sharp ridges above described being characteristic of lavas flowing on more level ground or down slightly inclined planes. When they descend very steep slopes the very moderate thickness which they attain is alone sufficient to preclude the possible formation of undulations like those just described, which are from 10 to 30 feet or more in height.

Cascades of lava at Salto della Giumenta. — Some very instructive examples are to be seen at various points on Mount Etna of the external form and internal structure assumed by currents of lava of known date which have flowed down very steep slopes. To one of these, which was precipitated in 1819 down a precipice which forms the head of the valley of Calanna, allusion has already been made, page 29. This precipice, called the Salto della Giumenta, is about 400 feet high and several hundred wide. In the annexed drawing, fig. 91, which I made in 1828, it is seen in profile with a branch of the lava of 1819 *a*, flowing over it. Fig. 92 is a front

view of the same, which I sketched in 1858, when a much more copious stream of melted matter (part of the current of 1852)

Fig. 91.

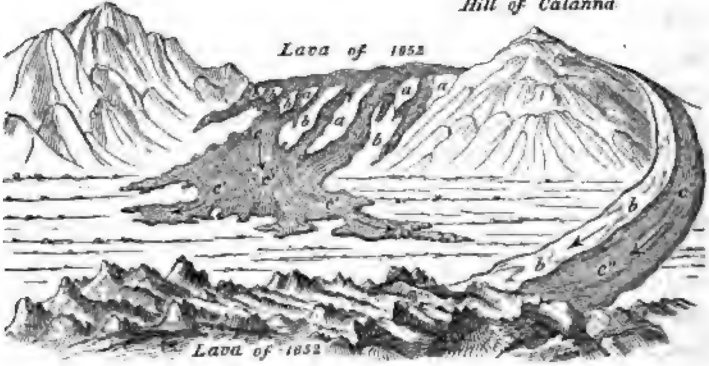


Modern lavas, as they appeared in 1828, descending the precipice called the Salto, at the head of the valley of Calanna, and flowing round the hill of that name.

A. Zoccolaro.
B. Monte di Calanna.
C. Plain at the head of the Valley of Calanna.
a. Lava of 1819 descending the precipice called Salto della Giumenta, and flowing through the valley.
b. Lavas of 1811 and 1819 flowing round the hill of Calanna.

had cascaded down the same height and overflowed the plain below. The greater part, however, of the same current *c*, like

Hill of Zoccolaro Fig. 92. *Hill of Calanna*



Lava of 1852 cascading down the precipice called Salto della Giumenta.

a, *a*. Portions of the face of the precipice composed of rocks like those of Zoccolaro and Calanna, which have not been concealed by the modern lavas.
b. Lava of 1819 which flowed down and encrusted the face of the precipice.
b——>*b*. Same lava passing round the promontory of Calanna, together with the lava of 1811 which had followed the same course.
c. Lava of 1852 which cascaded over the precipice.
c'. The same lava overflowing the level plain of the valley of Calanna.
c''. Same lava flowing round the promontory and covering parts of the older currents of 1811 and 1819.

its predecessors of 1811 and 1819, turned round the promontory formed by the Hill of Calanna, and moving right onwards has been piled up on the left side of the valley of Calanna so as to heighten its boundary wall without flowing down into it.

Both the lavas of 1819 and 1852 had been covered originally in every part where they congealed on the face of the steep precipice with the usual scoriaceous crust. But this crust, about three feet thick, had been washed off by rain at several places, and had exposed to view a solid and continuous stony layer below. The rock is somewhat vesicular, and contains crystals of felspar, augite, and olivine, with some titaniferous iron. As it is inclined at angles of from 35° to 50°, it affords a striking refutation of the doctrine that stony layers can only consolidate on slopes of from 3° to 5°.

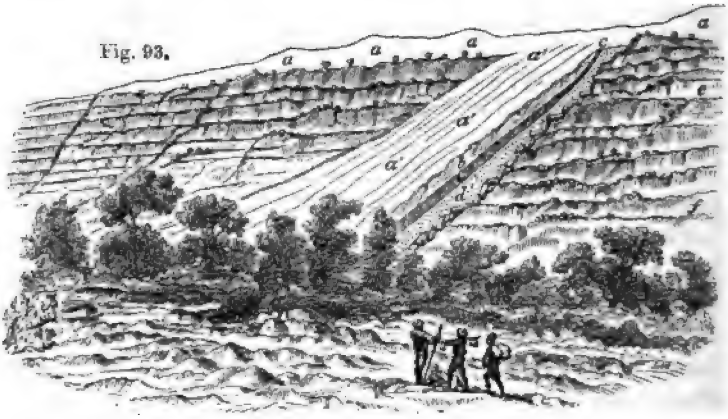
Inclined lava of Cava Grande.—Among other examples attesting the erroneousness of the notion just alluded to, I may call attention to another cascade of lava the internal structure of which is still more clearly exposed to view. On the eastern flank of Etna, north of Milo, is a deep and narrow gully called the Cava Grande (see Map, fig. 77, p. 10), which, although usually dry, has been entirely excavated through successive beds of ancient lava and scoriæ by the waters of occasional floods, which cascade over a perpendicular precipice of a horseshoe form, at the upper end of the ravine. The torrent is gradually cutting its way backwards, and thus adding to the length of the narrow valley. I witnessed, October 1857, several avalanches of sand and stones loosened from the terminal cliff by the heavy rains of the preceding day. The boundary walls of the opposite sides of the Cava Grande are 220 feet high, in part vertical, in part sloping at angles of between 38° and 65°.

In the year 1689, a lava stream descended from the Val del Bove in a direction nearly parallel to the Cava Grande, but a portion of its left side was precipitated into the ravine in the manner represented at *a′ a′ a′* in figure 93.

In addition to the retrogressive excavation of the head of the ravine caused by the torrent before mentioned, the steep boundary precipices are also undergoing constant waste, by which means a clear vertical section of the interior structure

of the current a' a is exposed to view as shown in the diagrams, figs. 93 and 94. It is evident that when the lava

Fig. 93.



Highly inclined lava of Cava Grande. From a sketch made October 1857.

a, a. Main stream of lava of 1689 flowing eastward.

a', a'. Branch of the same lava cascading northwards into the ravine called the Cava Grande, with a mean inclination of 35°.

b. Section of upper or scoriaceous part of the current, 6 feet thick.

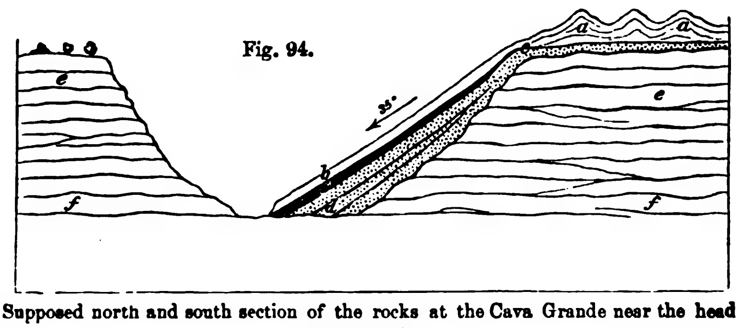
c, c. Solid layer of stony lava from 2½ to 5 feet thick, inclined at an angle of 35° and at its upper extremity at 47°.

d. Scoriaceous beds forming the base of the stream *a', a'*, and underlying the stony layer *c*.

e, f. Cliff containing 10 ancient lava currents of Etna, appearing horizontal, but being in fact inclined at 7° to the east, or towards the sea.

reached the edge of the precipice, fragments of the solid crust with much loose scoriæ first rolled down, producing a talus by which the general slope of the cliff was reduced to

Fig. 94.



Supposed north and south section of the rocks at the Cava Grande near the head of the ravine.

a, a. Lava of 1689 with lofty parallel east and west ridges.

b, c, d, e, f. Same as in fig. 93.

an angle of between 30° and 35°. Near the top, however, at *c*, part of the lava consolidated at an angle of 47°, the stony layer *c* being there only 2½ feet thick, whereas it has twice that thickness where it is less inclined (viz. at 35°) below. The rock formed on this steep slope is as compact as our ordinary ancient trap-rocks, and has the same specific gravity as commonly belongs to them. It contains crystals of felspar, and a small quantity of olivine. It is divided by a few joints at right angles to the cooling surfaces.

Flood of 1755 *in the Val del Bove.*—Before I allude to the action of running water in excavating ravines on the flanks of Etna, it may be well to mention the only instance on record of a great body of water having passed from the higher region of the mountain through the Val del Bove. This occurred in the year 1755. An eruption had taken place at the summit of the volcano, in the month of March, a season when the top of the mountain was covered with snow. The Canon Recupero, a good observer, and a man of great sagacity, was commissioned by Charles of Bourbon, king of Naples, to report on the nature and cause of the catastrophe. He accordingly visited the Val del Bove in the month of June, three months after the event, and found that the channel of the recent flood, nearly two miles broad, was still strewed over with sand and fragments of rock to the depth of 34 feet.

The volume of water in a length of one mile he estimated at 16,000,000 cubic feet, and he says that it ran at the rate of a mile in a minute and a half for the first twelve miles. At the upper end of the Val del Bove, all the pre-existing inequalities of the ground, for a space of two miles in length, and one in breadth, were perfectly levelled up and made quite even, and the marks of the passage of the flood were traceable from thence up the great precipice (or Balzo di Trifoglietto), to the Piano del Lago, or highest platform. Recupero, in his report, maintains that if all the snow on Etna, which he affirms is never more than four feet deep (some chasms we presume excepted), were melted in one instant, which no current of lava could accomplish, it would not have supplied such a volume of water. He came therefore

to the somewhat startling conclusion, that the water was vomited forth by the crater itself, and was driven out from some reservoir in the interior of the mountain.*

It seems to me very unlikely that the Canon, who was on the ground within three months of the date of the catastrophe, could have been mistaken in regard to the region whence the waters came. His conclusions on that head seem to have been legitimately deduced from the fact that the wreck of the inundation was traceable continuously from the sea-shore at Riposto up to the highest cone or its immediate neighbourhood. I am, therefore, inclined to suspect that at the time of the eruption of 1755 there was upon the summit of Etna, not only the winter's snow of that year, but many older layers of ice alternating with volcanic sand and lava, at the foot or in the flanks of the cone, which were suddenly melted by the permeation through them of hot vapours, and the injection into them of melted matter.

Glacier preserved by a covering of lava.—I stated in 1828,† that I ascertained the fact of the existence of a glacier under lava near the Casa Inglese, on the SE. side of the highest cone, and that it had been quarried during the previous summer, affording a supply of ice to the Catanians, at the close of an unusually hot season. On returning thirty years afterwards (September 1858), I found the same mass of ice, of unknown extent and thickness, still unmelted. It had been quarried only five years before, to the depth of four feet on the very same spot. My guide told me that he had seen this mass of solid ice, the bottom of which they did not reach, and that it was overlaid by ten feet of sand, and the sand again by lava.

Signor Mario Gemmellaro had satisfied himself in 1828, that nothing but the subsequent flowing of the lava over the snow could account for the position of the glacier. We may suppose that, at the commencement of the eruption, a deep mass of drift snow had been covered by volcanic sand showered down upon it before the descent of the lava. A dense stratum of this fine dust mixed with scoriæ is well

* Recupero, Storia dell' Etna, p. 85.

† Principles of Geology, 1st edition, p. 369.

known to be an extremely bad conductor of heat; and the shepherds in the higher regions of Etna are accustomed to provide water for their flocks during summer, by strewing a layer of volcanic sand a few inches thick over the snow, which effectually prevents the heat of the sun from penetrating.

Suppose the mass of snow to have been preserved from liquefaction until the lower part of the lava had consolidated, we may then readily conceive that a glacier thus protected, at the height of 10,000 feet above the level of the sea, would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below. When I first visited the summit of the highest cone in the beginning of winter (December 1st, 1828), I found the crevices in the interior encrusted with thick ice, and in some cases hot vapours were actually streaming out between masses of ice and the rugged and steep walls of the crater. Paradoxical, therefore, as it may appear, we cannot doubt that a great mass of ice was preserved from melting, by the singular accident of a current of lava flowing over it.

If, then, glaciers may endure for a series of years under volcanic sand and lava, the store of water which Recupero speculated upon as contained somewhere in the interior of the mountain, seems sufficiently accounted for. I am also now disposed to attach more importance than when I first wrote on this subject, to the tales of the mountaineers, which Recupero thought worth recording. They related to him that the water was boiling, that it was as salt as the sea, and that it brought down with it sea-shells to the coast. Now it will be seen that the hypothesis above suggested would very naturally account for the water being hot, and it may have been impregnated with saline matter exhaled from fumeroles on the sides of the cone or from the crater itself during the eruption, and these exhalations without giving to it the composition of sea-water, may have taken away its freshness. As to the story of the marine shells, if the flood, after issuing from the Val del Bove, cut deeply through the superficial lava or the alluvium between Milo and Giarre, it may have reached some of the beds of the subjacent Newer Pliocene

clay, at the height of 1,000 or 1,200 feet above the sea, washing out of it fossil shells of living species strong enough to bear transportation as far as Riposto.

Ancient valleys of Etna.—The action of volcanos is, as we have already seen, characteristically intermittent even when they are in a phase of frequent eruption; but we have good reason to believe that if their history could be known for thousands of years, we should find that there are very long periods, during which they lie dormant, and then have their fires resuscitated. From Junghuhn's account of the numerous cones of Java it appears that these volcanos are subject to protracted periods of inaction, during which valleys, deepening as they descend, are eroded by running water on all their sides; at length a paroxysmal outburst occurs, by which part of the cone is destroyed, and then lavas again pour out from time to time. Mr. Dana, in his account of the great cones of the Sandwich Islands, states, that the comparative length of the periods during which any one of them has been at rest may be estimated by the depth and size of the valleys which furrow their sides; but the time which such denudation may have occupied has often been so vast that we cannot attempt, with our present knowledge, to form any conjecture as to its duration.

From what was said of Vesuvius in the last chapter, the reader is aware that until the year 79 of our era, it had all the characters of an extinct volcano. The only part of the exterior of the ancient cone which still retains that physiognomy by which the whole of it must have been characterised before the renewal of its volcanic activity, is the northern side, scarcely ever visited by travellers, and which we have described as being intersected by numerous deep ravines, radiating as from a central axis towards all points of the compass. On ascending several of these ravines, we have seen that they terminate abruptly in perpendicular precipices from 60 to 300 feet in height, where in the rainy season there are waterfalls.* Above the head of such precipices shallow valleys continue upwards to the crest of the boundary wall of the Atrio del Cavallo, and no doubt were once con-

* See Vol. I. p. 635.

tinued to near the summit of the old cone of Somma, before that mountain was truncated in the year 79.

In like manner I conceive that, long before the historical era, Mount Etna may have been furrowed on all sides by valleys during a long interval of comparative rest, or, perhaps, a total suspension of eruptions.

The vast deposits of alluvial matter, more than 100 feet thick, which are seen along the coast eastward of the Val del Bove, between Giarre and Mangano, and which may sometimes be traced up to the height of 400 feet, attest the enormous amount of erosion which the eastern flanks of Etna have undergone at a remote period.

At length one or more paroxysmal outbreaks, to which the Val del Bove may have owed its origin, ushered in a period of renewed activity to which the lateral cones are principally due. The lavas pouring out successively on the northern, western, and southern flanks obliterated all the ancient valleys on those three sides, and would have done the same on the eastern flank of the cone had they not been intercepted in their course by that huge chasm, the Val del Bove, which they have already, in great part, filled up. Three valleys or ravines, which have escaped obliteration, deserve notice as bearing the same relation to the margin of the Val del Bove which the valleys on the north of Vesuvius (those of the Casa dell' Acqua and others, described at page 635, Vol. I.) bear to the Atrio del Cavallo. These three valleys on the south-east side of Etna are the Valle del Tripodo, the Valle dei Zappini, and the Valle di Calanna, the position of which will be seen in the Map, fig. 77, p. 10. The first of them, the Valle del Tripodo, although not difficult of access from Zafarana, is scarcely ever visited by travellers. It is a beautiful, wooded, Alpine ravine down which a torrent flows. On reaching the head of this ravine, or the col which divides it from the Val del Bove, a truly splendid view is obtained of all the grand features of that vast amphitheatre before described. Although the col is no less than 7,000 feet high above the level of the sea, it forms the lowest part of a deep notch in the southern escarpment of the Val del Bove or the Serra del Solfizio. (See Map, fig. 77.) The depth of the

gap must be great, as it enables an observer, looking at Etna from a vessel at sea off Aci Castello, to get a view of the Val del Bove through the opening. This notch is a section of a ravine of denudation once continuous with the Valle del Tripodo, which furrowed the old cone before the Val del Bove was formed.

The second valley, called 'dei Zappini,' runs parallel to the former, and is similar in its geological features though less grand. The torrents that drain both of them are swallowed up at their lower end in the holes and grottoes of the great lava current of 1792, which, flowing down from a different and higher part of Etna, crossed the channels of these torrents and blocked up the ravines in which they flow.

The third valley, that of Calanna before alluded to, is the most interesting because at its upper end we find the precipice before described, figs. 91 and 92, p. 34, over which the modern lavas of 1819 and 1852 have cascaded. There can be no doubt that this precipice, the Salto della Giumenta, was the site of a waterfall when a river flowed down from the ancient cone, before the origin of the Val del Bove. The space between the hills of Zoccolaro and Calanna indicates the place of the upper valley, while the Salto was formed by the river cutting its way backwards after the manner of the stream in the Cava Grande before described, p. 35, or of the retrograding torrents of Vesuvius, or, to compare small things with great, the river Niagara at its falls.

If Vesuvius continues to be as active as it has been for the last eighteen centuries, its lavas may one day top the crest of the Atrio and cascade over the precipices at the head of the Casa del' Acqua and the Fosso di Cancharoni, in the same way as the Etnean streams of 1819 and 1852 have cascaded down the Salto della Giumenta.

Antiquity of the cone of Etna.—It was before remarked (Vol. I., p. 89) that confined notions in regard to the quantity of past time have tended, more than any other prepossessions, to retard the progress of sound theoretical views in geology; the inadequacy of our conceptions of the earth's antiquity having cramped the freedom of our speculations in this science, very much in the same way as a belief in the exist-

ence of a vaulted firmament once retarded the progress of astronomy. It was not until Descartes assumed the indefinite extent of the celestial spaces, and removed the supposed boundaries of the universe, that just opinions began to be entertained of the relative distances of the heavenly bodies; and until we habituate ourselves to contemplate the possibility of an indefinite lapse of ages having been comprised within each of the modern periods of the earth's history, we shall be in danger of forming most erroneous and partial views in geology.

If history had bequeathed to us a faithful record of the eruptions of Etna, and 100 other of the principal active volcanos of the globe, during the last 3,000 years,—if we had an exact account of the volume of lava and matter ejected during that period, and the times of their production,—we might, perhaps, be able to form a correct estimate of the average rate of the growth of a volcanic cone. For we might thus obtain a mean result by the comparison of the eruptions of so great a number of vents, however irregular might be the development of the igneous action in any one of them, if contemplated singly during a brief period.

It would be necessary to balance protracted periods of inaction against the occasional outburst of paroxysmal explosions. Sometimes we should have evidence of a repose of sixteen centuries, like that which was interposed in Ischia, between the end of the fourth century B.C. and the beginning of the fourteenth century of our era.* Occasionally a tremendous eruption like that of Jorullo or that of Papandayang and others alluded to at page 11, would be recorded, giving rise at once to a new mountain, or to the truncation of an ancient cone, or to some vast lateral cavity like the Val del Bove. But the comparative rarity of such catastrophes exalts our conception of the great duration of the intervals of rest which occur between eras of paroxysmal violence.

If we desire to approximate to the age of Etna, we ought first to obtain some data in regard to the thickness of matter which has been added during the historical era, and then endeavour to estimate the time required for the accumulation

* See Vol. I. p. 606.

of such alternating lavas and beds of sand and scoriæ as are superimposed upon each other in the Val del Bove; afterwards we should try to deduce, from observations on other volcanos, the more or less rapid increase of burning mountains in all the different stages of their growth.

Although it is possible that some of the ancient eruptions of which the products are seen in the walls of the Val del Bove were on as grand a scale as those of our own time or even grander, yet we should in vain seek for evidence that any one of those ancient currents equalled in volume the lavas of 1669 or those of 1852.

There is a considerable analogy between the mode of increase of a volcanic cone and that of trees of *exogenous* growth. These trees augment, both in height and diameter, by the successive application externally of cone upon cone of new ligneous matter; so that if we make a transverse section near the base of the trunk, we intersect a much greater number of layers than nearer to the summit. When branches occasionally shoot out from the trunk, they first pierce the bark, and then, after growing to a certain size, if they chance to be broken off, they may become inclosed in the body of the tree, as it augments in size, forming knots in the wood, which are themselves composed of layers of ligneous matter, cone within cone.

In like manner, a volcanic mountain consists, as we have seen, of a succession of conical masses enveloping others, while lateral cones, having a similar internal structure, often project in the first instance, like branches from the surface of the main cone, and then becoming buried again, are hidden like the knots of a tree.

We can ascertain the age of an oak or pine by counting the number of concentric rings of annual growth seen in a transverse section near the base, so that we may know the date at which the seedling began to vegetate. The Baobab-tree of Senegal (*Adansonia digitata*) is supposed to exceed almost any other in longevity. Adanson inferred that one which he measured, and found to be thirty feet in diameter, had attained the age of 5,150 years. Having made an incision to a certain depth, he first counted 300 rings

of annual growth, and observed what thickness the tree had gained in that period. The average rate of growth of younger trees, of the same species, was then ascertained, and the calculation made according to a supposed mean rate of increase. De Candolle considers it not improbable that the celebrated Taxodium of Chapultepec, in Mexico (*Cupressus disticha* Linn.), which is 117 feet in circumference, may be more aged.

It is, however, impossible, until more data are collected respecting the average intensity of the volcanic action, to make anything like an approximation to the age of a cone like Etna; because, in this case, each successive envelope of lava and scoriæ is not of simultaneous growth round the mountain, like the layers of wood round a tree, and therefore affords us no corresponding and definite measure of time. Each conical envelope is made up of a great number of distinct lava currents and showers of sand and scoriæ differing in width and depth, and also the results of intermittent action exceedingly variable as to intensity and frequency of recurrence. Yet we cannot fail to form the most exalted conception of the antiquity of this mountain, when we consider that its base is about 90 miles in circumference; so that it would require 90 flows of lava, each a mile in breadth at its termination, to raise the present foot of the volcano as much as the average height of one lava current.

The injection of several thousand dikes into the mass of matter previously accumulated, is more comparable, as M. E. de Beaumont has hinted, to the endogenous growth of a tree, implying the stretching outwards and perhaps upwards also of the mountain. But observations within the historical era are too imperfect to enable us to decide whether the mountain has gained or lost in altitude at those periods when new fissures have been formed and filled.

Of the 80 most conspicuous minor cones which adorn the flanks of Etna, only one of the largest, Monti Rossi, has been produced within the times of authentic history. Even this hill, thrown up in the year 1669, although 450 feet in height, only ranks as a cone of second magnitude. Monte Minardo, near Bronte, rises, even now, to the height of 750 feet,

although its original base has been elevated by more modern lavas and ejections. It must also be remembered, that of the small number of lava streams which are poured forth in a century, one only is estimated to issue from the summit of Etna for every two that proceed from the sides. Nor do all the lateral eruptions give rise to such hills as would be reckoned amongst the 200 lateral cones before alluded to, p. 2, as laid down in Waltershausen's map. Some of them produce merely insignificant monticules, which are soon after overwhelmed by showers of ashes proceeding from higher vents.

How many years, then, must we not suppose to have been expended in the formation of all the minor cones? If we could strip off from Etna the whole of those now visible, together with the lavas and scoriæ that have been poured out from them, and from the highest crater, during the period of their growth, the diminution of the entire mass would be extremely slight; Etna might lose, perhaps, several miles in diameter at its base, but the aspect of the woody region would not be essentially changed, because other minor cones, now concealed, would be recalled as it were into existence by the removal of the lava and ejected matter under which they now lie buried. As to the height of the mountain during the early stages of the phase of lateral eruptions, it may have been much greater before its summit was truncated than it is now, even if we make allowance for a slight accession of height due to the gradual upheaval of the whole mass above the level of the sea, as testified by the raised beaches on the coast before described.

To attempt to estimate the number of centuries which have elapsed since the first submarine eruptions began would be idle, because there may have been periods of tranquillity such as that in which the ancient valleys were excavated, enduring perhaps for tens of thousands of years, and then followed by paroxysmal outbursts like that to which the Val del Bove may have owed its origin.

No general deluge can have occurred in the forest zone of Etna since the lateral cones were thrown up. For few, if any, of these heaps of loose scoriæ could fail to have been

swept away by a great flood, and any remaining would have exhibited some signs of its denuding action. To some, perhaps, it may appear that hills of such incoherent materials cannot be of very great antiquity, because the mere action of the atmosphere must, in the course of several thousand years, have obliterated their original forms. But there is no weight in this objection; for although the steep slopes of Monti Rossi, being still bare and composed in great part of light scoriæ and fine volcanic sand, have been acted upon both by wind and rain within the memory of persons now living, yet the older hills have been protected from waste ever since they have been covered with trees and herbage. Even before dense vegetation has been established, such is the porosity of their component materials, that almost all the rain which falls upon them is instantly absorbed; and for the same reason that the rivers on Etna have subterranean courses, there are no rills descending the sides of the minor cones.

In conclusion, I may remind the reader that, however vast may be the lapse of ages which we require for the growth of a mountain like Etna, there has been ample time for its passage through every phase of its development. Its foundations were laid in the sea, in the Newer Pliocene Period—that sea in which the shells of Aci Castello and Trezza flourished. We have seen at p. 6 that the events of the Glacial Period, though they may have occupied several hundred thousand years, do not reach back to an era when the assemblage of marine testacea differed as much as those of Aci Castello and Trezza differ from the fauna now characterising the neighbouring parts of the Mediterranean.

CHAPTER XXVII.

VOLCANIC ERUPTIONS—*concluded.*

VOLCANIC ERUPTION IN ICELAND IN 1783—NEW ISLAND THROWN UP—LAVA CURRENTS OF SKAPTÁR JOKUL, IN SAME YEAR—THEIR IMMENSE VOLUME—ERUPTION OF JORULLO IN MEXICO—HUMBOLDT'S THEORY OF THE CONVEXITY OF THE PLAIN OF MALPAIS—ERUPTION OF GALONGOON IN JAVA—SUBMARINE VOLCANOS—GRAHAM ISLAND, FORMED IN 1831—VOLCANIC ARCHIPELAGOS—SUBMARINE ERUPTIONS IN MID-ATLANTIC—THE CANARIES—CONES THROWN UP IN LANCEROTE, 1730-36—SANTORIN AND ITS VOLCANIC ERUPTIONS—BARREN ISLAND IN THE BAY OF BENGAL—MUD VOLCANOS—MINERAL COMPOSITION OF VOLCANIC PRODUCTS.

Volcanic Eruptions in Iceland.—With the exception of Etna and Vesuvius, the most complete chronological records of a series of eruptions are those of Iceland, for their history reaches as far back as the ninth century of our era; and from the beginning of the twelfth century, there is clear evidence that, during the whole period, there has never been an interval of more than forty, and very rarely one of twenty years, without either an eruption or a great earthquake. So intense is the energy of the volcanic action in this region, that some eruptions of Hecla have lasted six years without ceasing. Earthquakes have often shaken the whole island at once, causing great changes in the interior, such as the sinking down of hills, the rending of mountains, the desertion by rivers of their channels, and the appearance of new lakes.* New islands have often been thrown up near the coast, some of which still exist; while others have disappeared, either by subsidences or the action of the waves.

In the interval between eruptions, innumerable hot springs afford vent to the subterranean heat, and solfataras discharge copious streams of inflammable matter. The volcanos in different parts of this island are observed, like those of the

* Von Hoff, vol. ii. p. 393.

Phlegræan Fields, to be in activity by turns, one vent often serving for a time as a safety-valve to the rest. Many cones are often thrown up in one eruption, and in this case they take a linear direction, running generally from north-east to south-west from the north-eastern part of the island, where the volcano Krabla lies, to the promontory Reykianas.

Great eruption of Skaptár Jokul in 1783.—*New island thrown up.*—The convulsions of the year 1783 appear to have been more tremendous than any recorded in the modern annals of Iceland; and the original Danish narrative of the catastrophe, drawn up in great detail, has since been substantiated by several English travellers, particularly in regard to the prodigious extent of country laid waste, and the volume of lava produced.* About a month previous to the eruption of Skaptár Jokul on the mainland, presently to be mentioned, a submarine volcano burst forth in the sea in lat. 63° 25′ N., long. 23° 44′ W., at a distance of 30 miles in a south-west direction from Cape Reykianas, and ejected so much pumice, that the ocean was covered with that substance to the distance of 150 miles, and ships were considerably impeded in their course. A new island was formed, from which fire, smoke, and pumice were emitted at different points. This island was claimed by his Danish Majesty, who denominated it Nyöe, or the New Island; but before a year hád elapsed the sea resumed its ancient domain, and nothing was left but a reef of rocks from 5 to 30 fathoms under water.

Earthquakes which had long been felt in Iceland, became violent on June 11, 1783, when Skaptár Jokul, distant nearly 200 miles from Nyöe, threw out a torrent of lava which flowed down into the Skaptâ, and completely dried it up. The channel of the river was between high rocks, in many places from 400 to 600 feet in depth, and near 200 in breadth.

* The first narrative of the eruption was drawn up by Stephenson, then Chief Justice in Iceland, appointed commissioner by the King of Denmark for estimating the damage done to the country, that relief might be afforded to the sufferers. Henderson was enabled to correct some of the measurements given by Stephenson, of the depth, width, and length of the lava currents, by reference to the MS. of Mr. Paulson, who visited the tract in 1794, and examined the lava with attention. (Journal of a Residence in Iceland, &c., p. 229.) Some of the principal facts are also corroborated by Sir William Hooker, in his 'Tour in Iceland,' vol. ii. p. 128.

Not only did the lava fill up this great defile to the brink, but it overflowed the adjacent fields to a considerable extent. The burning flood, on issuing from the confined rocky gorge, was then arrested for some time by a deep lake, which formerly existed in the course of the river, between Skaptardal and Aa, which it entirely filled. The current then advanced again, and reaching some ancient lava full of subterraneous caverns, some of them apparently filled with water, melted parts of the rock and blew up others, throwing large fragments to the height of 150 feet into the air. On June 18, another ejection of liquid lava rushed from the volcano, which flowed down with amazing velocity over the surface of the first stream. By the damming up of the mouths of some of the tributaries of the Skaptâ, many villages were completely overflowed with water, and thus great destruction of property was caused. The lava, after flowing for several days, was precipitated down a tremendous cataract called Stapafoss, where it filled a profound abyss, which that great waterfall had been hollowing out for ages, and after this, the fiery current again continued its course.

On August 3, fresh floods of lava still pouring from the volcano, a new branch was sent off in a different direction; for the channel of the Skaptâ was now so entirely choked up, and every opening to the west and north was so obstructed, that the melted matter was forced to take a new course, so that it ran in a south-east direction, and discharged itself into the bed of the river Hverfisfliot, where a scene of destruction scarcely inferior to the former was occasioned. These Icelandic lavas (like the ancient streams which are met with in Auvergne, and other provinces of Central France) are stated by Stephenson to have accumulated to a prodigious depth in narrow rocky gorges; but when they came to wide alluvial plains, they spread themselves out into broad burning lakes, sometimes from 12 to 15 miles wide, and 100 feet deep. When the 'fiery lake' which filled up the lower portion of the valley of the Skaptâ had been augmented by new supplies, the lava flowed up the course of the river to the foot of the hills from whence the Skaptâ takes its rise. This affords a parallel case to one

which can be shown to have happened at a remote era in the volcanic region of the Vivarais in France, where lava issued from the cone of Thueyts, and while one branch ran down, another more powerful stream flowed up, the channel of the river Ardêche.

The sides of the valley of the Skaptâ present superb ranges of basaltic columns of older lavas, resembling those which are laid open in the valleys descending from Mont Dor in Auvergne, where more modern lava currents, on a scale very inferior in magnitude to those of Iceland, have also usurped the beds of the existing rivers. The eruption of Skaptár Jokul did not entirely cease till the end of two years; and when Mr. Paulson visited the tract eleven years afterwards in 1794, he found columns of smoke (or vapour) still rising from parts of the lava, and several rents filled with hot water.*

Although the population of Iceland was very much scattered, and did not exceed 50,000, no less than twenty villages were destroyed, besides those inundated by water; and more than 9,000 human beings perished, together with an immense number of cattle, partly by the depredations of the lava, partly by the noxious vapours which impregnated the air, and, in part, by the famine caused by showers of ashes throughout the island, and the desertion of the coasts by the fish.

Immense volume of the lava.—But the extraordinary volume of melted matter produced in this eruption deserves the particular attention of the geologist. Of the two branches, which flowed in nearly opposite directions, the greater was 50, and the lesser 45 miles in length. The extreme breadth which the Skaptâ branch attained in the low countries was from 12 to 15 miles, that of the other about 7. The ordinary height of both currents was 100 feet, but in narrow defiles it sometimes amounted to 600. Professor Bischoff has calculated, that the mass of lava brought up from the subterranean regions by this single eruption 'surpassed in magnitude the bulk of Mont Blanc.'† But a more

* Henderson's Journal, &c., p. 228.

† Jameson's Phil. Journ. vol. xxvi. p. 291.

distinct idea will be formed of the dimensions of the two streams, if we consider how striking a feature they would now form in the geology of England, had they been poured out on the bottom of the sea after the deposition, and before the elevation of our secondary and tertiary rocks. The same causes which have excavated valleys through parts of our marine strata, once continuous, might have acted with equal force on the igneous rocks, leaving, at the same time, a sufficient portion undestroyed to enable us to discover their former extent. Let us, then, imagine the termination of the Skaptá branch of lava to rest on the escarpment of the inferior and middle oolite, where it commands the vale of Gloucester. The great platform might be 100 feet thick, and from 10 to 15 miles broad, exceeding any which can be found in Central France. We may also suppose great tabular masses to occur at intervals, capping the summit of the Cotswold Hills between Gloucester and Oxford, by Northleach, Burford, and other towns. The wide valley of the Oxford clay would then occasion an interruption for many miles; but the same rocks might recur on the summits of Cumnor and Shotover Hills, and all the other oolitic eminences of that district. On the chalk of Berkshire, other tabular masses, 6 or 7 miles wide, might again be found; and, lastly, crowning the highest sands of Highgate and Hampstead, we might behold some remnants of the current 500 or 600 feet in thickness, causing those hills to rival, or even to surpass, in height, Salisbury Craigs and Arthur's Seat.

The distance between the extreme points here indicated would not exceed 90 miles in a direct line; and we might then add, at the distance of nearly 200 miles from London, along the coast of Dorsetshire and Devonshire, for example, a great mass of igneous rocks, to represent the submarine reef of the island of Nyöe. An eminent French writer declared in 1829 that *all* geological phenomena took place in ancient times on a scale of magnitude a hundredfold greater than those which are witnessed in our days, but it would be difficult to point out a mass of igneous rock of ancient date (distinctly referable to a single eruption) which

would even rival in volume the matter poured out from Skaptár Jokul in 1783.

Eruption of Jorullo in 1759.—As another example of the stupendous scale of modern volcanic eruptions, I may mention that of Jorullo in Mexico, in 1759. The great region to which this mountain belongs has already been described. The plain of Malpais forms part of an elevated platform, between 2,000 and 3,000 feet above the level of the sea, and is bounded by hills composed of basalt, trachyte, and volcanic tuff, clearly indicating that the country had previously, though probably at a remote period, been the theatre of igneous action. From the era of the discovery of the New World to the middle of the last century, the district had remained undisturbed, and the space, now the site of the volcano, which is 36 leagues distant from the nearest sea, was occupied by fertile fields of sugar-cane and indigo, and watered by the two brooks Cuitimba and San Pedro. In the month of June, 1759, hollow sounds of an alarming nature were heard, and earthquakes succeeded each other for two months, until, at the end of September, flames issued from the ground, and fragments of burning rocks were thrown to prodigious heights. Six volcanic cones, composed of scoriæ and fragmentary lava, were formed on the line of a chasm which ran in the direction from NNE. to SSW. The least of these cones was 300 feet in height; and Jorullo, the central volcano, was elevated 1,600 feet above the level of the plain. It sent forth great streams of basaltic lava, containing included fragments of granitic rocks, and its ejections did not cease till the month of February, 1760.*

Humboldt visited the country more than forty years after this occurrence, and was informed by the Indians, that when they returned, long after the catastrophe, to the plain, they found the ground uninhabitable from the excessive heat. When he himself visited the place, there appeared, around the base of the cones, and spreading from them, as from a centre, over an extent of four square miles, a mass of matter of a convex form, about 550 feet high at its junction with the cones,

* Daubeny on Volcanos, p. 337.

and gradually sloping from them in all directions towards the plain. This mass was still in a heated state, the temperature in the fissures being on the decrease from year to year, but in 1780 it was still sufficient to light a cigar at the depth of a few inches. On this slightly convex protuberance, the slope of which must form an angle of about 6° with the horizon, were thousands of flattish conical mounds, from 6 to 9 feet high, which, as well as large fissures traversing the plain, acted as fumeroles, giving out clouds of sulphurous acid and hot aqueous vapour. The two small rivers before mentioned disappeared during the eruption, losing themselves

Fig. 95.

a. Summit of Jorullo. b, c. Inclined plane sloping at an angle of 6° from the base of the cones.

below the eastern extremity of the plain, and reappearing as hot springs at its western limit.

Cause of the convexity of the plain of Malpais.—Humboldt attributed the convexity of the plain to inflation from below; supposing the ground, for four square miles in extent, to have risen up in the shape of a bladder to the elevation of 550 feet above the plain in the highest part. But Mr. Scrope has suggested that the phenomena may be accounted for far more naturally, by supposing that lava, flowing simultaneously from the different orifices and principally from Jorullo, formed, by the overflow of one sheet or stream upon another, a thick bed of imperfectly liquid basaltic lava, which acquired great thickness about its source, gradually thinning off towards the outer limits of the elliptical area which it covered, and thus producing a convex surface. Fresh supplies were probably emitted successively during the course of an eruption which lasted more than half a year; and some of these, resting on those first emitted, might only spread to a small distance from the foot of the cone, where they would necessarily accumulate to a great height. The average slope of the great dome-shaped volcanos of the Sandwich Islands, formed almost exclusively of lava, with scarce any scoriæ, is between 6° 30′ and 7° 46′, so that the inclination of the convex mass

around Jorullo, if we adopt Mr. Scrope's explanation (see fig. 95), is quite in accordance with the known laws which govern the flow of lava.

The showers, also, of loose and pulverulent matter from the six craters, and principally from Jorullo, would be composed of heavier and more bulky particles near the cones, and would raise the ground at their base, where, mixing with rain, they might have given rise to the stratum of black clay, which is described as covering the lava. The small conical mounds (called 'hornitos,' or little ovens) may resemble those five or six small hillocks which existed in 1823 on the Vesuvian lava, and sent forth columns of vapour, having been produced by the disengagement of elastic fluids heaving up small dome-shaped masses of lava. The fissures mentioned by Humboldt as of frequent occurrence, are such as might naturally accompany the consolidation of a thick bed of lava, contracting as it congeals; and the disappearance of rivers is the usual result of the occupation of the lower part of a valley or plain by lava, of which there are many beautiful examples in the old lava currents of Auvergne. The heat of the 'hornitos' is stated to have diminished from the first; and Mr. Bullock, who visited the spot many years after Humboldt, found the temperature of the hot spring very low, a fact which seems clearly to indicate the gradual congelation of a subjacent bed of lava, which from its immense thickness may have been enabled to retain its heat for half a century. The reader may be reminded, that when we thus suppose the lava near the volcano to have been, together with the ejected ashes, more than 500 feet in depth, we merely assign a thickness which the current of Skaptár Jokul attained in some places in 1783.

Hollow sound of the plain when struck.—Another argument adduced in support of the theory of inflation from below, was, the hollow sound made by the steps of a horse upon the plain; which, however, proves nothing more than that the materials of which the convex mass is composed are light and porous. The sound called 'rimbombo' by the Italians is very commonly returned by *made ground* when struck sharply; and has been observed not only on the sides of Vesuvius and

other volcanic cones where there is a cavity below, but in such regions as the Campagna di Roma, composed in a great measure of tuff and porous volcanic rocks. The reverberation, however, may perhaps be assisted by grottos and caverns, for these may be as numerous in the lavas of Jorullo as in many of those of Etna; but their existence would lend no countenance to the hypothesis of a great arched cavity, four square miles in extent, and in the centre 550 feet high.*

No recent eruptions of Jorullo.—In a former edition I stated that I had been informed by Captain Vetch, that in 1819 a tower at Guadalaxara was thrown down by an earthquake, and that ashes, supposed to have come from Jorullo, fell at the same time at Guanaxuato, a town situated 140 English miles from the volcano. But Mr. Burkhardt, a German director of mines, who examined Jorullo in 1827, ascertained that there had been no eruption there since Humboldt's visit 1803. He went to the bottom of the crater, and observed a slight evolution of sulphurous acid vapours, but the 'hornitos' had entirely ceased to send forth steam. During the twenty-four years intervening between his visit and that of Humboldt, vegetation had made great progress on the flanks of the new hills, the rich soil of the surrounding country was once more covered with luxuriant crops of sugar-cane and indigo, and there was an abundant growth of natural underwood on all the uncultivated tracts.†

Galongoon, Java, 1822.—The mountain of Galongoon (or Galung Gung) was in 1822 covered by a dense forest, and situated in a fruitful and thickly-peopled part of Java. There was a circular hollow at its summit, but no tradition existed of any former eruption. In July, 1822, the waters of the river Kunir, one of those which flowed from its flanks, became for a time hot and turbid. On the following 8th of October a loud explosion was heard, the earth shook, and immense columns of hot water and boiling mud, mixed with burning brimstone, ashes, and lapilli, of the size of nuts, were projected from the mountain like a water-spout, with such

* See Scrope on Volcanos, p. 267.

† Leonhard and Bronn's Neues Jahrbuch, 1835, p. 36.

prodigious violence that large quantities fell beyond the river Tandoi, which is forty miles distant. Every valley within the range of this eruption became filled with a burning torrent, and the rivers, swollen with hot water and mud, overflowed their banks, and carried away great numbers of the people, who were endeavouring to escape, and the bodies of cattle, wild beasts, and birds. A space of twenty-four miles between the mountain and the river Tandoi was covered to such a depth with bluish mud that people were buried in their houses, and not a trace of the numerous villages and plantations throughout that extent was visible. Within this space the bodies of those who perished were buried in mud and concealed, but near the limits of the volcanic action they were exposed, and strewed over the ground in great numbers, partly boiled and partly burnt.

It was remarked, that the boiling mud and cinders were projected with such violence from the mountain, that while many remote villages were utterly destroyed and buried, others much nearer the volcano were scarcely injured.

The first eruption lasted nearly five hours, and on the following days the rain fell in torrents, and the rivers, densely charged with mud, deluged the country far and wide. At the end of four days (October 12th), a second eruption occurred more violent than the first, in which hot water and mud were again vomited, and great blocks of basalt were thrown to the distance of 7 miles from the volcano. There was at the same time a violent earthquake, and in one account it is stated that the face of the mountain was utterly changed, its summit broken down, and one side, which had been covered with trees, became an enormous gulf in the form of a semicircle. This cavity was about midway between the summit and the plain, and surrounded by steep rocks, said to be newly heaped up during the eruption. New hills and valleys are said to have been formed, and the rivers Banjarang and Wulna changed their course, and in one night (October 12th) 2,000 persons were killed.

The first intimation which the inhabitants of Bandong received of this calamity on October 8th, was the news that the river Wulna was bearing down into the sea the dead

bodies of men, and the carcasses of stags, rhinoceroses, tigers, and other animals. The Dutch painter Payen determined to travel from thence to the volcano, and he found that the quantity of the ashes diminished as he approached the base of the mountain. He alludes to the altered form of the mountain after the 12th, but does not describe the new semicircular gulf on its side.

The official accounts state that 114 villages were destroyed, and above 4,000 persons killed.*

Submarine volcanos.—Although we have every reason to believe that volcanic eruptions as well as earthquakes are common in the bed of the sea, it was not to be expected that many opportunities would occur to scientific observers of witnessing the phenomena. The crews of vessels have sometimes reported that they have seen in different places sulphurous smoke, flame, jets of water, and steam, rising up from the sea, or they have observed the waters greatly discoloured, and in a state of violent agitation as if boiling. New shoals have also been encountered, or a reef of rocks just emerging above the surface, where previously there was always supposed to have been deep water. On some few occasions the gradual formation of an island by submarine eruption has been observed, as that of Sabrina, in the year 1811, off St. Michael's in the Azores. The throwing up of ashes in that case, and the formation of a cone about 300 feet in height, with a crater in the centre, closely resembled the phenomena usually accompanying a volcanic eruption on land. Sabrina was soon washed away by the waves. Previous eruptions in the same part of the sea were recorded to have happened in 1691 and 1720. The rise of Nyöe, also, a small island off the coast of Iceland, in 1783, has already been alluded to; and another volcanic isle was produced by an eruption near Reikiavig, on the same coast, in June, 1830.†

Graham Island,‡ 1831.—We have still more recent and

* Van der Boon Mesch, de Incendiis Montium Javæ, &c. Lugd. Bat. 1826; and Official Report of the President, Baron Van der Capellen; also, Von Buch, Isles Canar., p. 424.

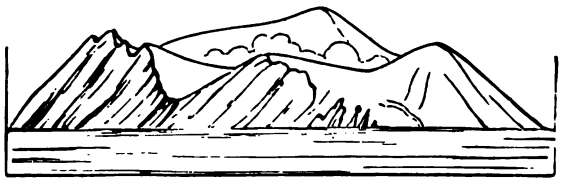
† Journ. de Géol. tome i.

‡ In a former edition, I selected the name of Sciacca out of seven which had been proposed; but the Royal and Geographical Societies have now adopted

minute information respecting the appearance, in 1831, of a new volcanic island in the Mediterranean, between the SW. coast of Sicily and that projecting part of the African coast where ancient Carthage stood. The site of the island was not any part of the great shoal, or bank, called 'Nerita,' as was first asserted, but a spot where Captain (Admiral) W. H. Smyth had found, in his survey a few years before, a depth of more than 100 fathoms' water.*

The position of the island (lat. 37° 1′ 30″ N., long. 12° 42′ 15″ E.) was about 30 miles SW. of Sciacca, in Sicily, and 33 miles NE. of the Island of Pantellaria.† On June 28, about a fortnight before the eruption was visible, Sir

Fig. 96.



Form of the cliffs of Graham Island, as seen from SSE., distant one mile, 7th August, 1831.‡

Pulteney Malcolm, in passing over the spot in his ship, felt the shocks of an earthquake, as if he had struck on a sand-bank; and the same shocks were felt on the west coast of Sicily, in a direction from SW. to NE. About July 10, John Corrao, the captain of a Sicilian vessel, reported that, as he passed near the place, he saw a column of water like a water-spout 60 feet high, and 800 yards in circumference, rising from the sea, and soon afterwards a dense steam in its place, which ascended to the height of 1,800 feet. The same Corrao, on his return from Girgenti, on July 18, found a small island, 12 feet high with a crater in its centre, ejecting

Graham Island; a name given by Capt. Senhouse, R.N., the first who succeeded in landing on it. The seven rival names are Nerita, Ferdinanda, Hotham, Graham, Corrao, Sciacca, Julia. As the isle was visible for only about three months, this is an instance of a wanton multiplication of synonyms which has scarcely ever been outdone even in the annals of zoology and botany.

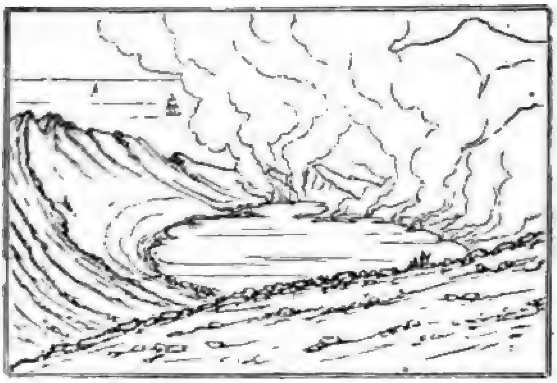
* Phil. Trans. 1832, p. 255.

† Journ. of Roy. Geograph. Soc. 1830–31.

‡ Phil. Trans., part ii., 1832, reduced from drawings by Captain Wodehouse, R.N.

volcanic matter, and immense columns of vapour; the sea around being covered with floating cinders and dead fish. The scoriæ were of a chocolate colour, and the water which boiled in the circular basin was of a dingy red. The eruption

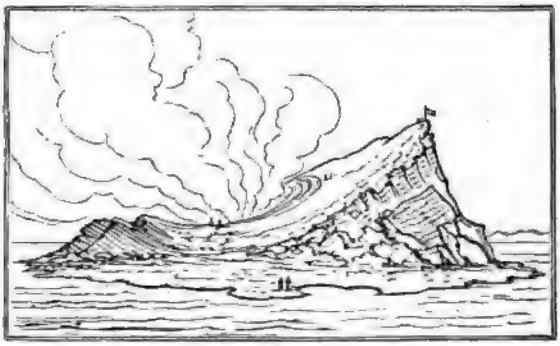
Fig. 97.



View of the interior of Graham Island, 29th Sept. 1831.

continued with great violence to the end of the same month; at which time the island was visited by several persons, and among others by Capt. Swinburne, R.N., and M. Hoffmann,

Fig. 98.



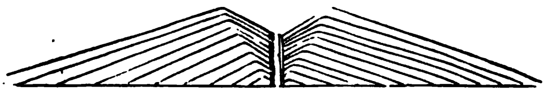
Graham Island, 29th Sept. 1831.*

the Prussian geologist. It was then from 50 to 90 feet in height, and ¾ of a mile in circumference. By August 4 it

* In the annexed sketch (fig. 98), drawn by M. Joinville, who accompanied M. C. Prevost, the beds seem to slope towards the centre of the crater; but I am informed by M. Prevost that these lines were not intended by the artist to represent the dip of the beds.

became, according to some accounts, above 200 feet high, and 3 miles in circumference; after which it began to diminish in size by the action of the waves, and was only 2 miles round on August 25; and on September 3, when it was carefully examined by Captain Wodehouse, only ⅗ of a mile in circumference; its greatest height being then 107 feet. At this time the crater was about 780 feet in circumference. On September 29, when it was visited by Mons. C. Prevost, the circumference of the island was reduced to about 700 yards. It was composed entirely of incoherent ejected matter, scoriæ, pumice, and lapilli, forming regular strata, some of which are described as having been parallel to the steep inward slope of the crater, while the rest were inclined outwards, like those of Vesuvius.* When the arrangement of the ejected materials has been determined by their falling continually on two steep slopes, that of the external cone and that of the crater, which is always a hollow inverted cone, a

Fig. 99.



transverse section would probably resemble that given in the annexed figure (99). But when I visited Vesuvius, in 1828, I saw no beds of scoriæ inclined towards the axis of the cone. (See fig. 73, Vol. I. p. 632.) Such may have once existed; but the explosions or subsidences, or whatever causes produced the great crater of 1822, had possibly destroyed them.

Few of the pieces of stone thrown out from Graham Island exceeded a foot in diameter. Some fragments of dolomitic limestone were intermixed; but these were the only non-volcanic substances. During the month of August, there occurred on the SW. side of the new island a violent ebullition and agitation of the sea, accompanied by the constant ascension of a column of dense white steam, indicating the existence of a second vent at no great depth from the surface. Towards the close of October, no vestige of the crater remained, and the island was nearly levelled with the surface of the ocean, with the exception, at one point, of a small

* See Memoir by M. C. Prevost, Ann. des Sci. Nat. tom. xxiv.

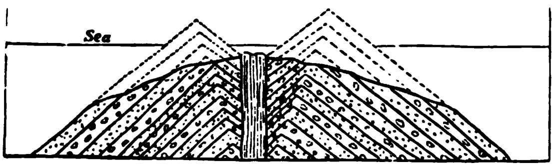
monticule of sand and scoriæ. It was reported that, at the commencement of the year following (1832), there was a depth of 150 feet where the island had been: but this account was quite erroneous; for in the early part of that year Captain Swinburne found a shoal and discoloured water thère, and towards the end of 1833 a dangerous reef existed of an oval figure, about $\frac{3}{8}$ of a mile in extent. In the centre was a black rock, of the diameter of about 26 fathoms, from 9 to 11 feet under water; and round this rock were banks of black volcanic stones and loose sand. At the distance of 60 fathoms from this central mass, the depth increased rapidly. There was also a second shoal at the distance of 450 feet SW. of the great reef, with 15 feet water over it, also composed of rock, surrounded by deep sea. We can scarcely doubt that the rock in the middle of the larger reef is solid lava, which rose up in the principal crater, and that the second shoal marks the site of the submarine eruption observed in August, 1831, to the SW. of the island.

From the whole of the facts above detailed, it appears that a hill 800 feet or more in height was formed by a submarine volcanic vent, of which the upper part (only about 200 feet high) emerged above the waters, so as to form an island. This cone must have been equal in size to one of the largest of the lateral volcanos on the flanks of Etna, and about half the height of the mountain Jorullo in Mexico, which was formed in the course of nine months, in 1759. In the centre of the new volcano a large cavity was kept open by gaseous discharges, which threw out scoriæ; and fluid lava probably rose up in this cavity. It is not uncommon for small subsidiary craters to open near the summit of a cone, and one of these may have been formed in the case of Graham Island; a vent perhaps, connected with the main channel of discharge, which gave passage in that direction to elastic fluids, scoriæ, and melted lava. It does not appear that, either from this duct, or from the principal vent, there was any overflowing of lava; but melted rock may have flowed from the flanks or base of the cone (a common occurrence on land), and may have spread in a broad sheet over the bottom of the sea.

The dotted lines in the annexed figure (fig. 100) are an imaginary restoration of the upper part of the cone, now removed by the waves: the strong lines represent the part of the volcano which is still under water: in the centre is a great column, or dike, of solid lava, 200 feet in diameter, supposed to fill the space by which the gaseous fluids rose; and on each side of the dike is a stratified mass of scoriæ and fragmentary lava. The solid nucleus of the reef, where the black rock is now found, withstands the movements of the sea; while the surrounding loose tuffs are cut away to a somewhat lower level. In this manner the lava, which was the lowest part of the island, or, to speak more correctly, which scarcely ever rose above the level of the sea when the island existed, has now become the highest point in the reef.

No appearances observed, either during the eruption or since the island disappeared, give the least support to the

Fig. 100.



Supposed section of Graham Island. (C. Maclaren.*)

opinion promulgated by some writers, that part of the ancient bed of the sea had been lifted up bodily.

The solid products, says Dr. John Davy, whether they consisted of sand, light cinders, or vesicular lava, differed more in form than in composition. The lava contained augite; and the specific gravity was 2·07 and 2·70. When the light spongy cinder, which floated on the sea, was reduced to fine powder by trituration, and the greater part of the entangled air got rid of, it was found to be of the specific gravity 2·64; and that of some of the sand which fell in the eruption was 2·75; † so that the materials equalled ordinary granites in weight and solidity. The only gas evolved in any considerable quantity was carbonic acid.‡

* Geol. of Fife and the Lothians, p. 41. Edin. 1839.

† Phil. Trans. 1832, p. 243.

‡ Ibid. p. 249.

Submarine eruptions in mid-Atlantic.—In the Nautical Magazine for 1835, p. 642, and for 1838, p. 361, and in the Comptes Rendus, April, 1838, accounts are given of a series of volcanic phenomena, earthquakes, troubled water, floating scoriæ and columns of smoke, which have been observed at intervals since the middle of the last century, in a space of open sea between longitudes 20° and 22° west, about half a degree south of the equator. These facts, says Mr. Darwin, seem to show, that an island or an archipelago is in process of formation in the middle of the Atlantic: a line joining St. Helena and Ascension would, if prolonged, intersect this slowly nascent focus of volcanic action.* Should land be eventually formed here, it will not be the first that has been produced by igneous action in this ocean since it was inhabited by the existing species of testacea. At Porto Praya in St. Jago, one of the Azores, a horizontal calcareous stratum occurs, containing shells of *recent* marine species, covered by a great sheet of basalt 80 feet thick.† It would be difficult to estimate too highly the commercial and political importance which a group of islands might acquire, if in the next two or three thousand years they should rise in mid-ocean between St. Helena and Ascension.

Eruption in Lancerote, 1730 *to* 1736.—An eruption happened in Lancerote, one of the Canary Islands, between the years 1730 and 1736, of which a detailed description was published by Von Buch, who visited that island in 1815, and compared the accounts transmitted to us of the event, with the present state and geological appearances of the country. During this outbreak, which lasted for five successive years, the flourishing town of St. Catalina and several other places were buried under lava and scoriæ 400 feet in thickness. Thirty cones were thrown up arranged in one line running nearly east and west and extending for a length of two geographical miles. The most elevated of these hills reached a height of about 600 feet above its base. The subterranean cleft from which elastic fluids escaped seems to have opened or widened at a succession of new points when the first apertures had become obstructed by solid lava or ejected

* Darwin's Volcanic Islands, p. 92. † Ibid. p. 6.

matter. From one of the fissures which was still open in 1815 Von Buch found hot vapours issuing which raised the thermometer to 145° Fahr., and were probably at the boiling point lower down. The exhalations seemed to consist of aqueous vapour; yet they could not be pure steam, for the crevices were encrusted on either side by siliceous sinter (an opal-like hydrate of silica of a white colour), which extended almost to the middle. This important fact attests the length of time during which chemical processes continue after eruptions, and shows how open fissures may be filled up by mineral matter, sublimed from volcanic exhalations.

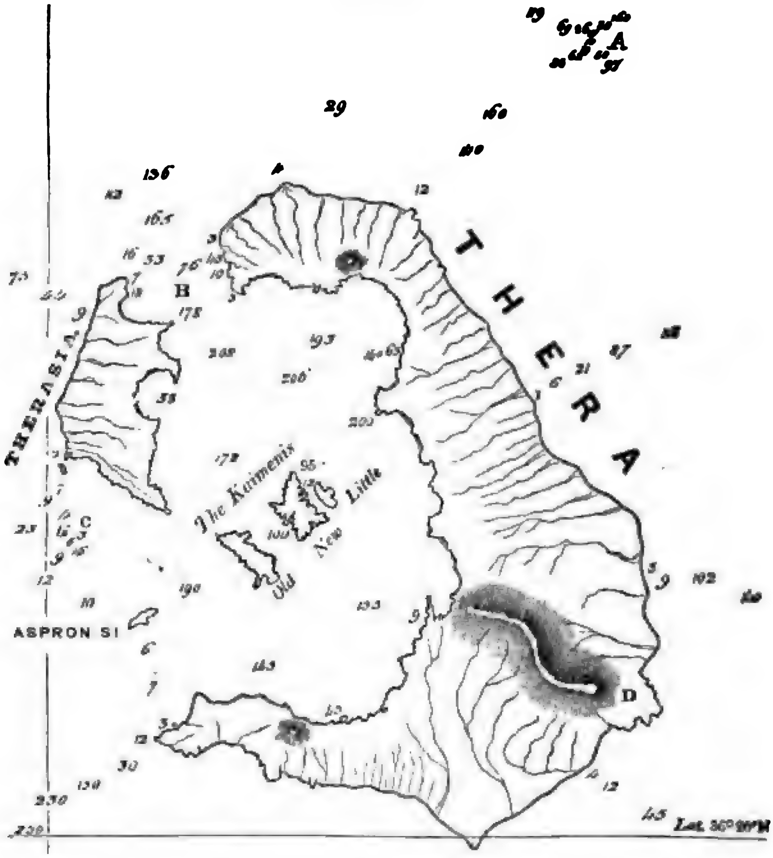
The quantity of dead fish which were strewed over the banks and shores of the island or floated on the waters on more than one occasion during this series of eruptions, some of them of species which had never before been observed, is said to have been indescribably great, especially where streams of lava entered the sea. This fact is one of geologieal interest, since many of the fossil fishes of ancient date, those of Monte Bolca for example, are preserved in volcanic tuff or in marls associated with contemporaneous igneous rocks. In August 1824 another eruption happened in Lanzerote near the port of Rescif, forming a cone and crater from which Mr. Hartung found hot vapours escaping during his visit in 1850.*

SANTORIN.

The Gulf of Santorin, in the Grecian Archipelago, has been for 2,000 years a scene of active volcanic operations. The largest of the three outer islands of the group (to which the general name of Santorin is given) is called Thera (or sometimes Santorin), and forms more than two-thirds of the circuit of the gulf. (See Map, fig. 101, p. 66.) The length of the exterior coast-line of this and the other two islands named Therasia and Aspronisi, taken together, amounts to about 30 miles, and that of the inner coast-line of the same islands to about 18 miles. In the middle of the gulf are three other islands, called the Little, the New, and the Old 'Kaimenis,' or 'Burnt Islands.' The accompanying

* G. Hartung, Lanzerote und Fuertaventura. 1856.

Fig. 101.

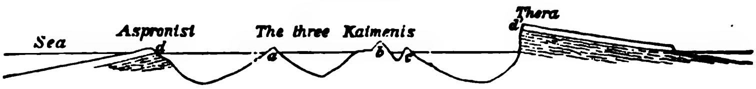


Map of Santorin in the Grecian Archipelago, from a Survey in 1848, by Captain Graves, R.N.

The soundings are given in fathoms.

A. Shoal formed by submarine volcanic eruption in 1650.
B. Northern entrance.
C. Mansell's Rock.
D. Mount St. Elias, 1,887 feet high.

Fig. 102.



Section of Santorin, in a NE. and SW. direction, from Thera through the Kaimenis to Aspronisi.

a. Old Kaimeni.
b. New Kaimeni.
c. Little Kaimeni.
d, d'. Great covering of white tufaceous agglomerate or of ejected matter containing fragments of brown trachyte.

map has been reduced from an Admiralty survey executed in 1848 by the late Captain Graves, R.N.

Pliny informs us that the year 186, B.C., gave birth to the Old Kaimeni, also called Hiera, or the 'Sacred Isle;' and in the year 19 of our era 'Theia' (the Divine) made its appearance above water, and was soon joined by subsequent eruptions to the older island, from which it was only 250 paces distant. The Old Kaimeni also increased successively in size in 726 and in 1427. A century and a half later, in 1573, another eruption produced the cone and crater called Micra-Kaimeni, or 'the Small Burnt Island.' The next great event which we find recorded occurred in 1650, when a submarine outbreak violently agitated the sea, at a point 3½ miles to the NE. of Thera, and which gave rise to a shoal (see A in the Map) carefully examined during the survey of 1848 by Captain Graves, and found to have 10 fathoms water over it, the sea deepening around it in all directions. This eruption lasted three months, covering the sea with floating pumice. At the same time an earthquake destroyed many houses in Thera, while the sea broke upon the coast, overthrew two churches, and exposed to view two villages, one on each side of the mountain of St. Stephen, both of which must have been overwhelmed by showers of volcanic matter during some previous eruptions of unknown date.* The accompanying evolution of sulphur and hydrogen issuing from the sea killed more than 50 persons, and above 1,000 domestic animals. A wave, also, 50 feet high, broke upon the rocks of the Isle of Nia, about 4 leagues distant, and advanced 450 yards into the interior of the Island of Sikino. Lastly, in 1707 and 1709, Nea-Kaimeni, or the New Burnt Island, was formed between the two others, Palaia and Micra, the Old and Little Isles. This isle was composed originally of two distinct parts; the first which rose was called the White Island, composed of a mass of pumice, extremely porous. Goree, the Jesuit, who was then in Santorin, says that the rock 'cut like bread,' and that, when the inhabitants landed on it, they found a multitude of full-grown fresh oysters adhering

* Virlet, Bull. de la Soc. Géol. de France, tom. iii. p. 103.

to it, which they ate.* This mass was afterwards covered, in great part, by the matter ejected from the crater of a twin-island formed simultaneously, and called Black Island, consisting of brown trachyte. The trachytic lava which rose on this spot appears to have been a long time in an intumescent state, for the New Kaimeni was sometimes lowered on one side while it gained height on the other, and rocks rose up in the sea at different distances from the shore and then disappeared again. The eruption was renewed at intervals during the years 1711 and 1712, and at length a cone was piled up to the height of about 330 feet above the level of the sea, its exterior slope forming an angle of 33° with the horizon, and the crater on its summit being 80 yards in diameter. In addition to the two points of subaërial eruption on the New and Little Kaimenis, two other cones, indicating the sites of submarine outbursts of unknown date, were discovered under water near the Kaimenis during the late survey.

In regard to the 'White Island,' which was described and visited by Goree in 1707, we are indebted to Mr. Edward Forbes for having, in 1842, carefully investigated the layer of pumiceous ash of which it is constituted. He obtained from it many shells of marine genera, Pectunculus, Arca, Cardita, Trochus, and others, both univalve and bivalve, all of recent Mediterranean species. They were in a fine state of preservation, the bivalves with the epidermis remaining, and valves closed, showing that they had been suddenly destroyed. Mr. Forbes, from his study of the habits of the mollusca living at different depths in the Mediterranean, was able to decide that such an assemblage of species could not have lived at a less depth than 220 feet, so that a bodily upheaval of the mass to that amount must have taken place in order to bring up this bed of ashes and shells to the level of the sea, and they now rise 5 or 6 feet above that level.†

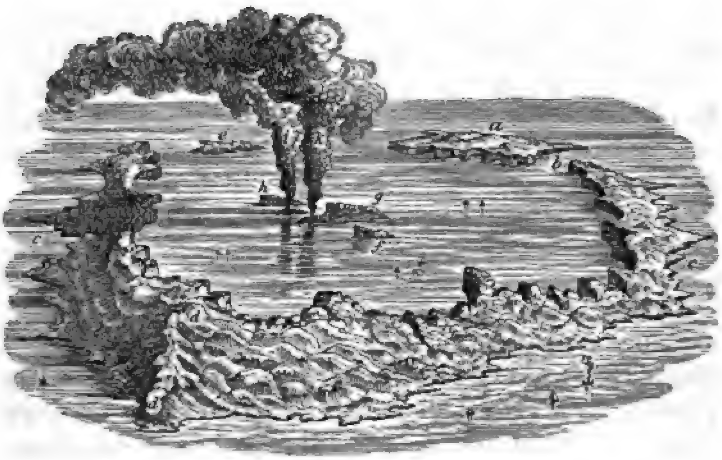
We may compare this partial elevation of solid matter to the rise of a hardened crust of scoriæ, such as is usually

* Phil. Trans. No. 332.

† E. Forbes, Brit. Association, Report for 1843, p. 177.

formed on the surface of lava currents, even while they are in motion, and which, although stony and capable of supporting heavy weights, may be upraised without bursting by the intumescence of the melted matter below. The reader may also be reminded of the upheaval of a solid crust of lava witnessed by Abich within the crater of Vesuvius in the year 1834, already mentioned by me. (Vol. I. p. 630.) That the upheaval was merely local is proved by the fact that the neighbouring Kaimenis did not participate in the movement, still less the three more distant or outer islands.

Fig. 103.



Bird's-eye view of the Gulf of Santorin during the volcanic eruption of February, 1866.

a. Therasia.
b. The 'northern entrance,' 1,068 feet deep.
c. Thera.
d. Mount St. Elias, rising 1,887 feet above the sea, composed of granular limestone and clay-slate, the only non-volcanic rocks in Santorin.
e. Aspronisi.
f. Little Kaimeni.
g. New Kaimeni.
h. Old Kaimeni.
i. Aphroessa.
k. George.

Eruption of 1866.—Another eruption broke out in Nea Kaimeni in February 1866. At the end of January the sea had been observed in a state of ebullition off the south-west coast, and part of the channel between New and Old Kaimeni marked 70 fathoms in the Admiralty chart had become, on February 11, only 12 fathoms deep. According to M. Julius Schmidt, a gradual rising of the bottom went on until

a small island made its appearance called afterwards Aphroessa.* (See i, fig. 103.) It seems to have consisted of lava pressed upwards and outwards almost imperceptibly by steam, which was escaping at every pore through the hissing scoriaceous crust. 'It could be seen,' says Commander Lindsay Brine, R.N., 'through the fissures in the cone that the rocks within were red-hot, but it was not till later that an eruption began.'† On February 11, the village of Vulcano on the south-east coast, where there had been a partial sinking of the ground, was in great part overwhelmed by the materials cast out from a new vent which opened in that neighbourhood, and to which the name of George was given (see *k*, fig. 103), which finally, according to Schmidt, became about 200 feet high. Commander Brine having ascended on February 28, 1866, to the top of the crater of Nea Kaimeni about 350 feet high, looked down upon the new vent then in full activity. The whole of the cone was swaying with an undulating motion to the right and left, and appeared sometimes to swell to nearly double its size and height, to throw out ridges like mountain spurs, till at last a broad chasm appeared across the top of the cone, accompanied by a tremendous roar of steam, and the shooting up from the new crater to the height of from 50 to 100 feet of tons of rock and ash mixed with smoke and steam. Some of these which fell on Micra-Kaimeni at a distance of 600 yards from the crater, measured 30 cubic feet. This effort over, the ridges slowly subsided, the cone lowered and closed in, and then, after a few minutes of comparative silence, the struggle would begin again with precisely similar sounds, action, and result. Threads of vapour escaping from the old crater of Nea Kaimeni proved that there was a subterranean connection between the old and new vents.'‡

Aphroessa, of which the cone was at length raised to a height of more than 60 feet, was united in August with the main island. This was due in part at least to the upheaval of the bottom of the sea, which is now only 7 fathoms deep

* Schmidt, cited by Von Hauer.

† Brine, Visit to Santorin. Royal Geographical Proc. Nov. 10th, 1866, vol. x. p. 317.

‡ Ibid.

in the channel dividing the New and Old Kaimenis, whereas in the Admiralty chart (see fig. 101, p. 66) the soundings gave 100 fathoms.

It will be seen by the map and section (figs. 101 and 102), that the Kaimenis are arranged in a linear direction, running NE. and SW., in a manner different from that represented in the older charts. In their longest diameter they form at their base a ridge nearly bisecting the gulf or crater.

Notwithstanding this linear arrangement we may compare the three Kaimenis in the centre of the gulf to the modern cone of Vesuvius, and consider the outer islands Thera, Aspronisi, and Therasia as the remains of an older and ruined cone like Somma. Thera, which constitutes alone more than two-thirds of the outer circuit, presents everywhere towards the gulf high and steep precipices composed of volcanic rocks. In all places near the base of its cliffs, a depth of from 800 to 1,000 feet of water was found, and Lieut. Leycester informs us that if the gulf, which is 6 miles in diameter, could be drained, a bowl-shaped cavity would appear with walls 2,449 feet high in some places, and even on the south-west side, where it is lowest, nowhere less than 1,200 feet high; while the Kaimenis would be seen to form in the centre a huge mountain 5½ miles in circumference at its base, with three principal summits (the Old, the New, and the Little Burnt Islands) rising severally to the heights of 1,251, 1,629, and 1,158 feet above the bottom of the abyss. The rim of the great cauldron thus exposed would be observed to be in all parts perfect and unbroken, except at one point where there is a deep and long chasm or channel, known by mariners as the 'northern entrance' (B, fig. 101, and *b*, fig. 103,) between Thera and Therasia, and called by Lieut. Leycester 'the door into the crater.' It is no less than 1,170 feet deep, and constitutes, as will appear by the soundings (see Map, fig. 101), a remarkable feature in the bed of the sea. There is no corresponding channel passing out from the gulf into the Mediterranean at any other point in the circuit between the outer islands, the greatest depth there ranging from 7 to 66 feet.

We may conceive, therefore, if at some former time the

whole mass of Santorin stood at a higher level by 1,200 feet, that this single ravine or narrow valley now forming 'the northern entrance,' was the passage by which the sea entered a circular bay.

But at a still earlier period when the ancient volcanic cone, of which the outer islands are the remains, was still more elevated above the level of the sea, there may have been a deep valley of subaërial erosion cut by the principal river which then drained Santorin, which may have consisted of one lofty volcanic cone afterwards truncated by a paroxysmal explosion such as we have already spoken of in the case of Galongoon, p. 57, and when treating of the supposed origin of the Val del Bove on Etna. It would then be necessary to imagine the subsidence and partial submergence of this original island in order to explain the present gulf and the deep channel (B, fig. 101) coinciding with the ancient gorge of fluviatile erosion.

All the outer islands Thera, Therasia, and Aspronisi are covered with one great uniform mass of volcanic matter, expressed by *d*, *d'*, in the section fig. 102, p. 66. This great overlying deposit has been called pumiceous by many observers, but M. Virlet says it is a white tufaceous agglomerate through which are dispersed fragments of a brown trachyte. Such a mass may well be imagined to be the product of that paroxysmal eruption by which so large a part of the great cone was destroyed, and the gulf formed, in the middle of which the Kaimenis have since been thrown up.

Thera, Therasia, and Aspronisi are exclusively composed of volcanic matter, except the southern part of Thera, where Mount St. Elias (*d d*, fig. 103) reaches an elevation of 1,887 feet above the sea, or three times the height now attained by the loftiest of the igneous rocks.* This mountain is formed of granular limestone and argillaceous schist, and is much more ancient than any part of the volcanic cone, one side of the base of which now abuts against it. The inclination, strike, and fractures of the calcareous and argillaceous strata of St. Elias have no relation to the great cone, but, according

* Virlet, Bull. de la Soc. Géol. de France, tome iii. p. 103.

to M. Bory St. Vincent, have the same direction as those of the other isles of the Grecian Archipelago, namely, from NNW. to SSE. Each of the three islands, Thera, Therasia, and Aspronisi, are composed of beds of trachytic lava and tuff, having a gentle inclination of only 3° or 4°. Each bed is very narrow and discontinuous, the successive layers being moulded or dove-tailed, as M. Virlet expresses it, into the inequalities of the previously existing surface, on which showers of cinders or streams of melted matter had been poured.

An important fact is adduced by M. Virlet, to show that the gentle dip of the lava streams in the three outer islands towards all points of the compass, away from the centre of the gulf, has not been due to the upheaval of horizontal beds, as conjectured by Von Buch, who had never visited Santorin.* The French geologist found that the vesicles or pores of the trachytic masses were lengthened out in the several directions in which they would have flowed if they had descended from the axis of a cone occupying the centre of the crater. For it is well known that the bubbles of confined gas in a fluid in motion assume an oval form, and the direction of their longer axis coincides always with that of the stream.

The absence of dikes in the cliffs surrounding the gulf is in favour of the theory that we here behold a section of the basal remains of an old volcanic cone. We have already spoken of the want of such dikes in those parts of the old Vesuvius (see Vol. I. p. 636) or Somma, as well as of Mount Etna, which are far from the original centres of eruption. (Vol. II. p. 17.) We may confidently infer from analogy that the missing part of the old cone of Santorin which rose to a great height where the Kaimenis now stand, consisted of steeply inclined lavas traversed by numerous vertical dikes.

If we adopt the hypothesis above suggested, we are required to assume a subsidence of more than 1,000 feet in order to explain the north-east channel (B, fig. 101, and *b*, fig. 103) as being a submerged valley or ravine of subaërial erosion. In reference to this point we may mention that a large part of Thera actually sank down during a great earthquake in

* Poggendorf's Annalen, 1836, p. 183.

1650, the subsidence being proved not only by tradition, but by the fact that a road which formerly led between two places on the east coast of Thera is now 12 fathoms under water. A long succession, no doubt, of such events would be demanded to bring about so great a submergence, and future geologists will have to decide whether this or some other theory will best account for this submarine chasm.

On a review, therefore, of all the facts now brought to light respecting Santorin, I attribute the moderate slope of the beds in Thera and the other external islands to their having originally descended the inclined flanks of a large volcanic cone, the principal orifice or vents of eruption having been always situated where they are now, in or near the centre of the space occupied by the gulf or crater, in other words where the outburst of the Kaimenis has been witnessed in historical times. The single long and deep opening into the crater is a feature common to all those remnants of ancient volcanos, the central portions of which have been removed, and is probably connected with aqueous denudation. As to the age of the more ancient volcanic formations of Santorin, I am informed by M. Fouqué that they belong to the Newer Pliocene Period, as shown by marine shells which he collected in 1866.*

Barren Island. — There is a great analogy between the structure of Barren Island in the Bay of Bengal, lat. 12° 15′, and that of Santorin last described. When seen from the ocean, this island presents, on almost all sides, a surface of bare rocks, rising, with a moderate acclivity, towards the interior; but at one point there is a cleft by which we can penetrate into the centre, and there discover that it is occupied by a great circular basin more than 8,000 feet in diameter bordered all around by steep rocks, in the midst of which rises a volcanic cone, very frequently in eruption. The height of the circular border which encloses the basin has been variously estimated. According to Von Liebig, who visited the island in 1857, it was about 1,000 feet high, corresponding in elevation to the modern cone, so that the latter can only be seen from the sea

* Splendid photographs and descriptions of the eruption of the Kaimenis in 1866 have been published by Messrs. Fritsch, Reiss, and Stübel. Trübner, London, 1867.

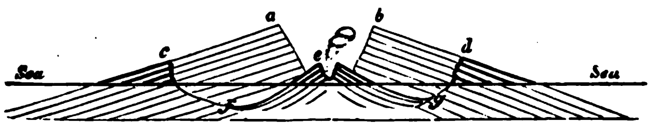
by looking through the ravine. The sides of this cone slope at angles of from 35° to 40°. In some of the older accounts the sea is described as entering the inner basin, but Von Liebig says it was excluded at the time of his visit, and that a stream of black lava 10 feet high was traceable from the interior

Fig. 104.

Cone and crater of Barren Island, in the Bay of Bengal. Height of the central cone (according to Capt. Miller, in 1834), 500 feet.*

to the outlet; there was also on the sides of the passage or inlet a raised beach 20 feet high, composed of volcanic tuff and rolled pebbles, indicative of a modern upheaval of the island to that extent. It is most probable that the exterior enclosure of Barren Island (*c*, *d*, fig. 105) is nothing more than

Fig. 105.



Supposed section of Barren Island, in the Bay of Bengal.

the remains of a truncated cone, *c*, *a*, *b*, *d*, a great portion of which has been removed by explosion, which may have preceded the formation of the new interior cone *f*, *e*, *g*.†

MUD VOLCANOS.

Iceland.—Professor R. Bunsen, in his account of the pseudo-volcanic phenomena of Iceland, describes many valleys where sulphurous and aqueous vapours burst forth

* The annexed view is given by Von Buch. Captain Horsburgh saw smoke proceeding from the crater in 1803.

† Von Liebig, Zeitschrift der Geologischen Gesellschaft, vol. x. p. 303. 1858.

with a hissing sound, from the hot soil formed of volcanic tuff. In such spots a pool of boiling water is seen, in which a bluish-black argillaceous paste rises in huge bubbles. These bubbles on bursting throw the boiling mud to a height of 15 feet and upwards, so that it accumulates in ledges round the crater or basin of the spring.

Baku on the Caspian.—The formation of a new mud volcano was witnessed on November 27, 1827, at Tokmali, on the peninsula of Abscheron, east of Baku. Flames blazed up to an extraordinary height, for a space of 3 hours, and continued for 20 hours more to rise about 3 feet above a crater, from which mud was ejected. At another point in the same district where flames issued, fragments of rock of large size were hurled up into the air and scattered around.*

Sicily.—At a place called Macaluba, near Girgenti in Sicily, are several conical mounds from 10 to 30 feet in height, with small craters at their summits, from which cold water, mixed with mud and bitumen, is cast out. Bubbles of carbonic acid and carburetted hydrogen gas are also disengaged from these springs, and at certain periods with such violence as to throw the mud to the height of 200 feet. These 'air volcanos,' as they are sometimes termed, are known to have been in the same state of activity for the last 15 centuries; and Dr. Daubeny imagines that the gases which escape may be generated by the slow combustion of beds of sulphur, which is actually in progress in the blue clay, out of which the springs rise.† But as the gases are similar to those disengaged in volcanic eruptions, and as they have continued to stream out for so long a period, they may perhaps be derived from a more deeply-seated source.

Beila in India.—In the district of Luss or Lus, south of Beila, about 120 miles NW. of Cutch and the mouths of the Indus (see Map, fig. 111, p. 98), numerous mud volcanos are scattered over an area of probably not less than 1,000 square miles. Some of these have been well described by Captain Hart, and subsequently by Captain Robertson, who has paid a visit to that region, and made sketches of them, which he has kindly placed at my disposal. From one of

* Humboldt's Cosmos. † Daubeny, Volcanos, p. 267.

these the annexed view has been selected. These conical hills occur to the westward of the Hara Mountains and the river Hubb. (See Map, p. 98.) One of the cones is 400 feet high, composed of light-coloured earth, and having at its summit a crater 30 yards in diameter. The liquid mud which fills the crater is continually disturbed by air-bubbles, and here and there is cast up in small jets.*

Fig. 106.

Mud cones and craters of Hinglaj near Beila, district of Lus, 120 miles north-west of mouth of the Indus. From original drawing by Capt. Robertson. (See Map, p. 98.)

Frequency of eruptions, and nature of subterranean igneous rocks.—When we speak of the igneous rocks of our own times, we mean that small portion which, during volcanic eruptions, reaches the surface, whether in the form of lava, scoriæ, or sand, being forced up from the interior by elastic fluids in a melted state, and cooling gradually in the sea or open air.

* See Buist, Volcanos of India, Trans. Bombay Geol. Soc. vol. x. p. 154, and Captain Robertson, Journ. of Roy. Asiat. Soc. 1850.

But we cannot obtain access to that which is congealed far beneath the surface under a pressure equal to that of many hundred, or many thousand, atmospheres.

During the last century, about 50 eruptions are recorded of the five European volcanic districts, of Vesuvius, Etna, Volcano (one of the Lipari Isles), Santorin, and Iceland; but many beneath the sea in the Grecian Archipelago and near Iceland may doubtless have passed unnoticed. If some of them produced no lava, others, on the contrary, like that of the Skaptár Jokul, in 1783, poured out melted matter for 5 or 6 years consecutively; which cases, being reckoned as single eruptions, will compensate for those of inferior strength. Now, if we consider the active volcanos of Europe to constitute about a fortieth part of those already known on the globe, and calculate that, one with another, they are about equal in activity to the burning mountains in other districts, we may then compute that there happen on the earth about 2,000 eruptions in the course of a century, or about 20 every year.

However inconsiderable, therefore, those rocks may be which the operations of fire produce on the surface, we must suppose the subterranean changes now constantly in progress to be on the grandest scale. The loftiest volcanic cones and the lavas which have flowed from their craters must be insignificant when contrasted with the products of heat in the nether regions. In regard to these last or those igneous rocks which have been formed in our own times in the bowels of the earth, whether in rents and caverns, or by the cooling of lakes of melted lava, we may safely infer that they are heavier and less porous than ordinary lavas, and more crystalline, although composed of the same mineral ingredients. As the hardest crystals produced artificially in the laboratory require the longest time for their formation, so we must suppose that where the cooling down of melted matter takes place by insensible degrees, in the course of ages, a variety of minerals will be produced far harder than any formed by natural processes within the short period of human observation.

These subterranean volcanic rocks, moreover, cannot be stratified in the same manner as sedimentary deposits from

water, although it is evident that when great masses consolidate from a state of fusion, they may separate into natural divisions; for this is seen to be the case in many lava currents. We may also expect that the rocks in question will often be rent by earthquakes, since these are common in volcanic regions; and the fissures will be often injected with similar matter, so that dikes of crystalline rock will traverse masses of similar composition. It is also clear, that no organic remains can be included in such masses, as also that these deep-seated igneous formations considered in mass must underlie all the strata containing organic remains, because the heat proceeds from below upwards, and the intensity required to reduce the mineral ingredients to a fluid state must destroy all organic bodies in rocks included in the midst of them.

If by a continued series of elevatory movements, such masses shall hereafter be brought up to the surface, in the same manner as sedimentary marine strata have, in the course of ages, been upheaved to the summit of the loftiest mountains, it is not difficult to foresee what perplexing problems may be presented to the geologist. He may then, perhaps, study in some mountain-chain the very rocks produced at the depth of several miles beneath the Andes, Iceland, or Java, in the time of Leibnitz, and draw from them the same conclusion which that philosopher derived from certain igneous products of high antiquity; for he conceived our globe to have been, for an indefinite period, in the state of a comet, without an ocean, and uninhabitable alike by aquatic or terrestrial animals.

CHAPTER XXVIII.

EARTHQUAKES AND THEIR EFFECTS.

EARTHQUAKES AND THEIR EFFECTS—DEFICIENCY OF ANCIENT ACCOUNTS—ORDINARY ATMOSPHERIC PHENOMENA—CHANGES PRODUCED BY EARTHQUAKES IN MODERN TIMES CONSIDERED IN CHRONOLOGICAL ORDER—EARTHQUAKE IN NEW ZEALAND—PERMANENT UPHEAVAL AND SUBSIDENCE OF LAND—A FAULT PRODUCED IN THE ROCKS—EARTHQUAKE IN SYRIA, 1837—EARTHQUAKES IN CHILI IN 1837 AND 1835—ISLE OF SANTA MARIA RAISED TEN FEET—CHILI, 1822—EXTENT OF COUNTRY ELEVATED—EARTHQUAKE OF CUTCH IN 1819—SUBSIDENCE IN THE DELTA OF THE INDUS—ISLAND OF SUMBAWA IN 1815—EARTHQUAKE OF CARACCAS IN 1812—SHOCKS IN THE VALLEY OF THE MISSISSIPPI AT NEW MADRID IN 1811.

IN the sketch given in Chapter XXIII. of the geographical boundaries of volcanic regions, I stated, that although the points of eruption are but thinly scattered, constituting mere spots on the surface of those vast districts, yet the subterranean movements extend simultaneously over immense areas. We may now proceed to consider the changes which these movements produce on the surface, and in the internal structure of the earth's crust.

Deficiency of ancient accounts.—It is only within the last two centuries, since Hooke first promulgated, in 1688, his views respecting the connection between geological phenomena and earthquakes, that the permanent changes effected by these convulsions have excited attention. Before that time, the narrative of the historian was almost exclusively confined to the number of human beings who perished, the number of cities laid in ruins, the value of property destroyed, or certain atmospheric appearances which dazzled or terrified the observers. The creation of a new lake, the engulphing of a city, or the raising of a new island, are sometimes, it is true, adverted to, as being too obvious, or of too much geographical or political interest to be passed over in silence. But no

researches were made expressly with a view of ascertaining the amount of depression or elevation of the ground, or any particular alterations in the relative position of sea and land; and very little distinction was made between the raising of soil by volcanic ejections, and the upheaving of it by forces acting from below. The same remark applies to a very large proportion of modern accounts: and how much reason we have to regret this deficiency of information appears from this, that in every instance where a spirit of scientific enquiry has animated the eye-witnesses of these events, facts calculated to throw light on former modifications of the earth's structure are recorded.

Phenomena attending earthquakes.—As I shall confine myself almost entirely, in the following notice of earthquakes, to the changes brought about by them in the configuration of the earth's crust, I may mention, generally, some accompaniments of these terrible events which are almost uniformly commemorated in history, so that it may be unnecessary to advert to them again. Irregularities in the seasons preceding or following the shocks; sudden gusts of wind, interrupted by dead calms; violent rains at unusual seasons, or in countries where, as a rule, they are almost unknown; a reddening of the sun's disk, and haziness in the air, often continued for months; an evolution of electric matter, or of inflammable gas from the soil, with sulphurous and mephitic vapours; noises underground, like the running of carriages, or the discharge of artillery, or distant thunder; animals uttering cries of distress, and evincing extraordinary alarm, being more sensitive than men to the slightest movement; a sensation like sea-sickness, and a dizziness in the head, experienced by men:—these, and other phenomena, less connected with our present subject as geologists, have recurred again and again at distant ages, and in all parts of the globe.

I shall now begin the enumeration of earthquakes with the latest authentic narratives, and so carry back the survey retrospectively, that I may bring before the reader, in the first place, the minute and circumstantial details of modern times, and thus enable him, by observing the extraordinary

amount of change within the last 170 years, to perceive how great must be the deficiency in the meagre annals of earlier eras.

EARTHQUAKES OF THE NINETEENTH CENTURY.*

New Zealand, 1855.—*Permanent upheaval and subsidence of land.*—In no country perhaps, where the English language is spoken, have earthquakes, or, to speak more correctly, the subterranean causes to which such movements are due, been so active in producing changes of geological interest as in New Zealand. The convulsions which have agitated this archipelago since it was first known to whalers or settlers, have visited different districts in succession.

The Rev. R. Taylor, many years a missionary in New Zealand, states that the shocks of 1826, 1841, and 1843 expended each of them their chief violence in distinct areas. In the year 1823, there was a small cove called the Jail, about 80 miles north of Dusky Bay, much visited by sealers, for it afforded suitable anchorage for their vessels, being sheltered by lofty cliffs, and having deep water so close to the shore that they could step out of their boats on to the rocks.

After a succession of earthquakes in 1826 and 1827, so complete was the transformation of this coast that its former features could no longer be recognised; the cove had become dry land, and trees were seen under water near the coast, having probably been carried down by landslips into what

* Since the publication of the first edition of this work, numerous accounts of recent earthquakes have been published; but as they do not illustrate any new principle, I cannot insert them, as they would enlarge too much the size of my work. The late Von Hoff published from time to time, in Poggendorf's Annalen, lists of earthquakes which happened between 1821 and 1836; and, by consulting these, the reader will perceive that every month is signalised by one or many convulsions in some part of the globe. See also Mallet's Dynamics of Earthquakes, Trans. Roy. Irish Acad. 1846; also Art. 'Earthquakes,' Admiralty Manual, 1849; also Mr. Mallet's reports on earthquakes to Brit. Assoc. 1850, 1852, and 1858, containing a complete catalogue of known earthquakes from 1606 B.C. to A.D. 1842; also remarks on the earthquakes of which accounts were published since that time by Prof. Alexis Perrey, of Dijon. A continued series of accounts of earthquakes and volcanic eruptions by the last-mentioned author, drawn up with great care, since 1842, has been published by the Royal Academy of Belgium, with the discussion of their causes and effect. See also Hopkins' Report, Brit. Assoc. 1847–8.

was previously deep water, for large masses are said to have slid down from the hills into the sea. The same writer informs us, that in 1847, the hull of a vessel was discovered on the western coast of the South Island. It was lying 200 yards inland, and was supposed to be the 'Active,' which was lost in 1814. A small tree was growing through its bottom, and Mr. Taylor suggests that the coast had risen, so as to cause the ocean to retire to a distance of 200 yards from the old shore line, where the vessel had been stranded; but a more precise investigation of the locality will be required before we can feel sure that the vessel was not carried in by a wave raised during the earthquake, for such waves have, in modern times, left much larger ships high and dry in the interior of Peru and some other countries.* (See p. 157.) The natives are said to have told our first settlers that they might expect a great earthquake every seven years; and although such exact periodicity has by no means been verified, the average number of violent shocks in a quarter of a century seems not to have fallen short of the estimate here referred to.

In the course of the year 1856, I had an opportunity of conversing in London with three gentlemen, all well qualified as scientific observers, who were eye-witnesses of the tremendous earthquake experienced in January of the preceding year in New Zealand. These were, Mr. Edward Roberts, of the Royal Engineers department; Mr. Walter Mantell, son of the celebrated geologist; and Mr. Frederick A. Weld, a landed proprietor in the South Island.† The earthquake occurred in the night of January 23, 1855, and was most violent in the narrowest part of Cook Strait, a few miles to the SE. of Port Nicholson (see Map, fig. 107, p. 84); but the shocks were felt by ships at sea 150 miles from the coast, and the whole area shaken of land and water is estimated at 360,000 square miles, an area three times as large as the British Isles. In the vicinity of Wellington, in the North Island, a tract of land comprising 4,600 square miles

* Rev. R. Taylor, 'New Zealand and its Inhabitants,' London, 1855.

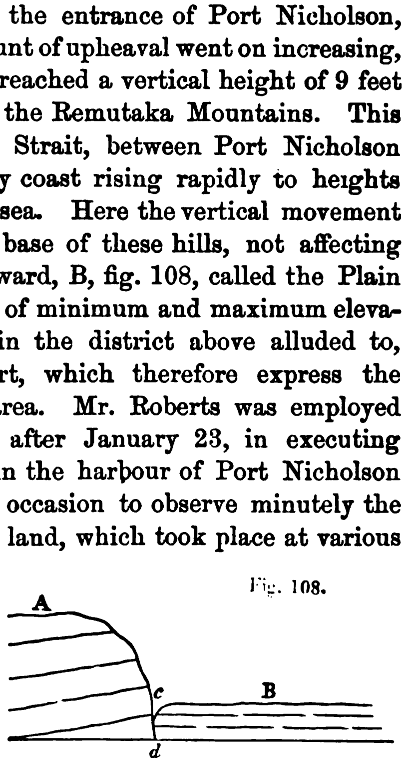
† This account was published by me in the Bulletin de la Soc. Géol. de France, 1856, p. 661.


SITE OF NEW ZEALAND EARTHQUAKE
OF JANUARY 23rd 1855.
COOK STRAIT
TASMAN BAY
CLOUDY BAY
WHITE BLUFF
C.CAMPBELL
WELLINGTON
NELSON
RIMUTAKA MOUNTAINS
WAIRARAPA VALLEY
NEW ZEALAND
NORTH ISLAND
SOUTH ISLAND

Fig. 197.

(not much inferior to Yorkshire in dimensions), is supposed by Mr. Roberts to have been permanently upraised from 1 to 9 feet. There was no perceptible elevation on the coast 16 miles N. of Wellington, but from that point to Pencarrow Head, on the east side, at the entrance of Port Nicholson, (see Map, fig. 107), the amount of upheaval went on increasing, somewhat gradually, till it reached a vertical height of 9 feet along the eastern flank of the Remutaka Mountains. This range terminates in Cook Strait, between Port Nicholson and Palliser Bay, in a lofty coast rising rapidly to heights about 4,000 feet above the sea. Here the vertical movement ceased abruptly along the base of these hills, not affecting the low country to the eastward, B, fig. 108, called the Plain of Wairarapa. The points of minimum and maximum elevation from NW. to SE., in the district above alluded to, are about 23 miles apart, which therefore express the breadth of the upraised area. Mr. Roberts was employed professionally, before and after January 23, in executing several government works in the harbour of Port Nicholson and on the coast, and had occasion to observe minutely the changes in the level of the land, which took place at various points, and especially in the sea-cliff, called Muka-Muka, 12 miles SE. of Wellington, where the eastern flank of the Remutaka range, before described, terminates southwards in Cook Strait. Here a distinct line of fault, *c*, *d*, fig. 108, was observed, the rocks on one side A, being raised vertically 9 feet, while the strata B, on the other side of the fissure *c*, *d*, experienced no movement. The uplifted mass A consists, according to Mr. Walter Mantell, of argillite, having the ordinary composition of clay slate, but not laminated. It presents a cliff, several hundred feet high towards the straits, whereas

Fig. 108.



Junction of argillite and tertiary strata at Muka-Muka cliff.*

A. Argillite. B. Tertiary strata. *c*, *d*. Line of vertical fissure and fault.

* I give this section from the description of my informants, and it must therefore be simply regarded as an explanatory diagram.

the horizontally stratified tertiary strata exposed to the eastward form a comparatively low cliff, not exceeding 80 feet in height. These tertiary strata, which are of marine origin, did not, as already stated, participate in the upward movement. Mr. Roberts was able to measure accurately the amount of permanent upheaval in the older formation, by observing the altered position of a white band of nullipores, with which the surface of the rock below the level of low tide had been coated. This white zone, a few hours after the earthquake, was found to be 9 feet above its former level. Previously to the shock, there had been no room to pass between the sea and the base of the perpendicular cliff called Muka-Muka, except for a short time at low water, and as the herdsmen were obliged to wait for low tide in order to drive their cattle past the cliff, Mr. Roberts was engaged in constructing a road there. But immediately after the upheaval, a gently sloping raised beach, more than 100 feet wide, was laid dry, affording ample space at all states of the tide for the passage of man and beast.

The junction of the older and newer rocks along the line of fault above described is marked in the interior of the country by a continuous escarpment running north and south along the base of the Remutaka Mountains, where the older rocks present a steep slope towards the east, or towards the great plain of the Wairarapa formed of the modern tertiary deposit before mentioned. The course of the fault along the base of the escarpment was rendered visible by a nearly perpendicular cliff of fresh aspect 9 feet in height and traceable in an inland direction to the extraordinary distance of about 90 miles, according to information given by Mr. Borlase, a settler who lived in the Wairarapa valley about 60 miles north of Cook Strait. It was marked, moreover, in many places by an open fissure into which cattle fell and could not in some cases be recovered, or by fissures from 6 to 9 feet broad filled here and there with soft mud and loose earth. At the same time that this vertical movement took place on January 23, the harbour of Port Nicholson, about 12 miles to the westward of Muka-Muka cliff, together with the valley of the Hutt, was raised from 4 to 5 feet, the greater elevation

being on the eastern, and the lesser on the western side of the harbour. A rock called the Balley Rock, a short distance from Evans Bay, was formerly 2 feet under water at the lowest tides, and a vessel having touched upon it, a buoy had been placed over it to mark its position. This rock projected after the shock nearly 3 feet above the surface of the water at low tide. The rise of the tide in the Hutt River was sensibly diminished by the earthquake. At the time of the convulsion great waves of the sea rolled in upon the coast, and for several weeks the tides were very irregular. Dead fish were left by a wave on the racecourse at Wellington, and Mr. Mantell states that others were also met with by several vessels in Cook Strait floating on the sea in surprising numbers, some of them of species never seen before by the fishermen.

Mr. Weld, who resided south of the Straits in the South Island, informed me that, besides experiencing there the shock of the 23rd, he felt another next morning of equal violence, and waves of the sea rolled in along the coast for a distance of 50 miles. At a place called the Flags between Cape Campbell and Waipapa (see Map), some men were loading a vessel with wood, when they saw distinctly an earthquake approaching them from a point called 'the White Rocks,' 3 miles to the northward. Its approach was rendered visible by the rolling of stones from the top of the cliffs, also by landslips and clouds of dust, and by the accompanying sea wave. Upon the whole it appears that the area convulsed in the South Island was not so extensive as that upheaved around Wellington, also that to the south of the Straits the direction of the movement was reversed, being for the most part a downward one. The valley of the Wairau, with parts of the adjoining coast, subsided about 5 feet, so that the tide flowed several miles farther up into the Wairau River than it formerly did, and ships taking in fresh water were obliged to go three miles farther up the river to obtain a supply, than they did before the earthquake.

There was no volcanic eruption, whether in the Northern or Southern Island, at the time of these events; but the natives allege that the temperature of the Taupo hot springs

(see small Map, p. 84) was sensibly elevated, just before the catastrophe.

I will now conclude this sketch of the changes produced in 1855 by observing that a question arose as to whether in the region about Port Nicholson the land, after it was upheaved several feet in January, sank again to some slight extent or a few inches in the course of 7 or 8 months, or before September 1855. When Mr. Roberts left New Zealand, three months after the earthquake, there had been no sinking of the upraised land, and he felt persuaded that he could not have failed to notice even a slight change of level had any occurred. He ascertained ten weeks after the shock that there had certainly been no subsidence whatever on the coast at Pencarrow Head, and the tides were so irregular long after the earthquake, in the harbour of Port Nicholson and elsewhere, that the supposed partial sinking of the coast which some believed to have taken place might perhaps be deceptive. It is surprising how soon the signs of a recent change of level on a coast are effaced to all eyes but those of the scientific observer, especially where there is a rise and fall of the tides. Rocks newly exposed soon begin to weather, and vegetation spreads over the emerged land, and a new beach, with all the characters of the old one, is formed in a few months along the sea-margin.

The geologist has rarely enjoyed so good an opportunity as that afforded him by this convulsion in New Zealand, of observing one of the steps by which those great displacements of the rocks called 'faults' may in the course of ages be brought about. The manner also in which the upward movement increased from north-west to south-east explains the manner in which beds may be made to dip more and more in a given direction by each successive shock.

An independent witness of the earthquake of January 1855, a civil engineer, says in a letter to Mr. Robert Mallet that 'the first and greatest shock of January 23 lasted about a minute and a half. All the brick buildings in Wellington were overthrown, as well as the bridge over the Hutt. The hillsides opposite Wellington, those of the Remutaka range, were much shaken, as evidenced by the many bare patches with which

they were chequered, fully to the extent of one-third of their surface, whence trees had been shaken off.' The ground in this range, he says, was more violently shaken than in Wellington, and the direction of the shock was NE. and SW., agreeing with that of the chain of hills. After the shock the tide did not come at high water within 3 or 4 feet of its former height.*

Mr. Weld was in the South Island during the previous earthquake of 1848, and he informed me that a great rent was then caused in a chain of mountains varying in height from 1,000 to 4,000 feet, which run southwards from the White Bluff in Cloudy Bay and may be considered a prolongation of the Remutaka or Tararua chain above alluded to. (See Map, p. 84.) This fissure of 1848 was not more than 18 inches in average width, but was remarkable for its length, for it was partly traced by Mr. Weld and partly by observers on whom he could rely, for 60 miles, striking north-north-east and south-south-west in a line parallel to the axis of the chain.

Syria, January, 1837.—It has been remarked that earthquakes affect elongated areas. The violent shock which devastated Syria in 1837 was felt on a line 500 miles in length by 90 in breadth: † more than 6,000 persons perished; deep rents were caused in solid rocks, and new hot springs burst out at Tabereah.

Chili—Valdivia, 1837.—One of the earthquakes by which in the present century the position of land is known to have been permanently altered is that which occurred in Chili, on November 7, 1837. On that day Valdivia was destroyed, and a whaler, commanded by Captain Coste, was violently shaken at sea, and lost her masts, in lat. 43° 38′ S. in sight of the land. On the following 11th of December the captain went to a spot near the island of Lemus, one of the Chonos archipelago, where he had anchored two years before, and he there found that the bottom of the sea had been raised more than 8 feet. Some rocks formerly covered at all times by the sea were now constantly exposed, and an enormous quantity of shells and fish in a decaying state, which had been thrown

* Reports of Brit. Assoc. 1858, p. 105.

† Darwin, Geol. Proceedings, vol. ii. p. 658.

there by the waves, or suddenly laid dry during the earthquake, attested the recent date of the occurrence. The whole coast was strewn with uprooted trees.*

Chili—Conception, 1835.—Fortunately we have a still more detailed account of the geographical changes produced in the same country on February 20, 1835. An earthquake was then felt at all places between Copiapo and Chiloe, nearly 1,000 miles from north to south, and from Mendoza to Juan Fernandez, about 500 miles from east to west. 'Vessels,' says Mr. Caldcleugh, 'navigating the Pacific, within 100 miles of the coast, experienced the shock with considerable force.' † Conception, Talcahuano, Chillan, and other towns, were thrown down. From the account of Captain Fitz Roy, R.N., who was then employed in surveying the coast, we learn that after the shock the sea retired in the Bay of Conception, and the vessels grounded, even those which had been lying in seven fathoms water: all the shoals were visible, and soon afterwards a wave rushed in and then retreated, and was followed by two other waves. The vertical height of these waves does not appear to have been much greater than 16 or 20 feet, although they rose to much greater heights when they broke upon a sloping beach.

According to Mr. Caldcleugh and Mr. Darwin, the whole volcanic chain of the Chilian Andes, a range 1,300 miles in length, was in a state of unusual activity, both during the shocks and for some time preceding and after the convulsion, and lava was seen to flow from the crater of Osorno. (See Map, fig. 109.) The island of Juan Fernandez, distant 365 geographical miles from Chili, was violently shaken at the same time, and devastated by a great wave. A submarine volcano broke out there near Bacalao Head, about a mile from the shore, in 69 fathoms water, and illumined the whole island during the night. ‡

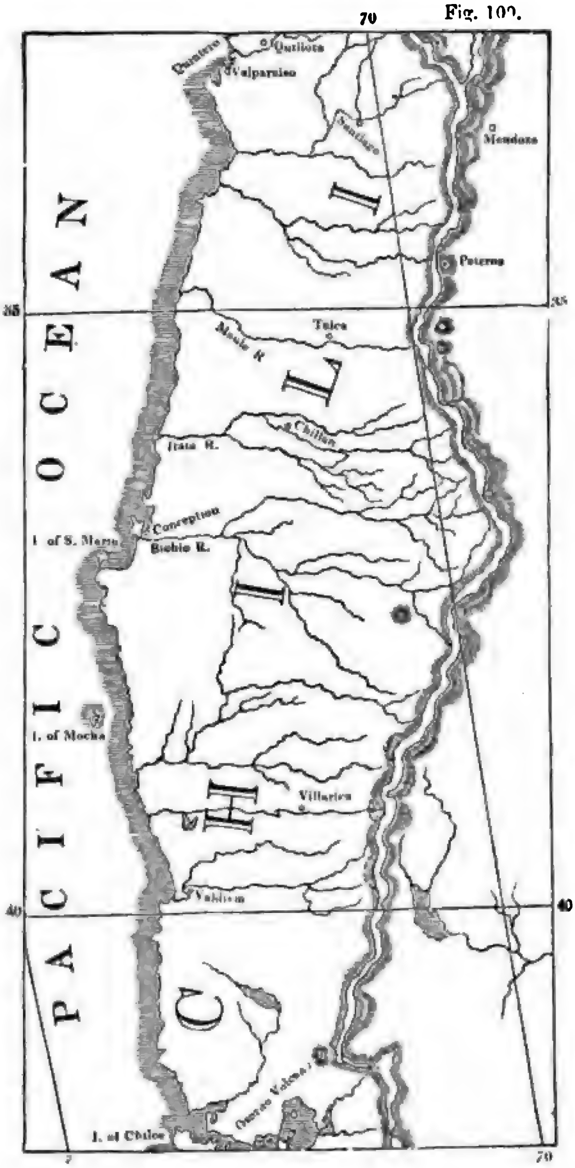
'At Conception,' says Captain Fitz Roy, 'the earth opened and closed rapidly in numerous places. The direction of the cracks was not uniform, though generally from south-east to

* Dumoulin, Comptes Rendus de l'Acad. des Sci. Oct. 1838, p. 706.

† Phil. Trans. 1836, p. 21.

‡ Ibid. 1826.

Fig. 109.

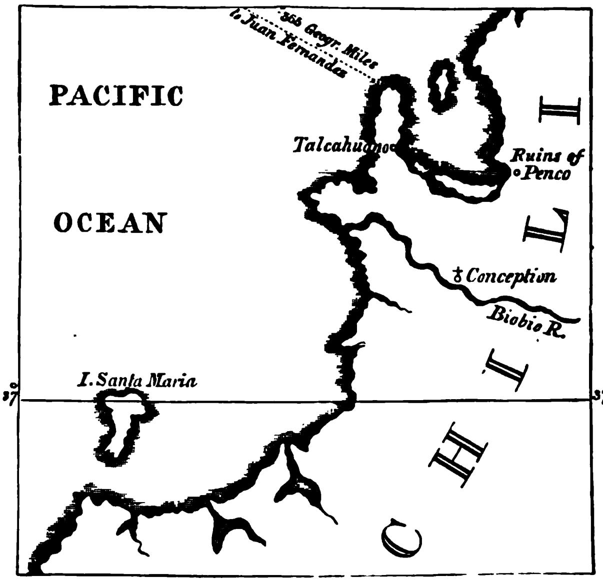


north-west. The earth was not quiet for three days after the great shock, and more than 300 shocks were counted between February 20 and March 4. The loose earth of the valley of

the Biobio was everywhere parted from the solid rocks which bound the plain, there being an opening between them from an inch to a foot in width.

'For some days after February 20, the sea at Talcahuano,' says Captain Fitz Roy, 'did not rise to the usual marks by 4 or 5 feet vertically. When walking on the shore, even at high water, beds of dead mussels, numerous chitons, and limpets, and withered sea-weed, still adhering, though lifeless, to the rocks on which they had lived, everywhere met the eye.' But this difference in the relative level of the land

Fig. 110.



Part of Chili altered by Earthquake of February, 1835.

and sea gradually diminished, till in the middle of April the water rose again to within 2 feet of the former highwater mark. It might be supposed that these changes of level merely indicated a temporary disturbance in the set of the currents, or in the height of the tides at Talcahuano; but, on considering what occurred in the neighbouring island of Santa Maria, Captain Fitz Roy concluded the land had been raised 4 or 5 feet in February, and that it had returned in April to within 2 or 3 feet of its former level.

Santa Maria, the island just alluded to, is about 7 miles long and 2 broad, and about 25 miles south-west of Conception. (See Map, p. 92.) The phenomena observed there are most important. 'It appeared,' says Captain Fitz Roy, who visited Santa Maria twice, the first time at the end of March, and afterwards in the beginning of April, 'that the southern extremity of the island had been raised 8 feet, the middle 9, and the northern end upwards of 10 feet. On steep rocks, where vertical measurements could be correctly taken, beds of dead mussels were found 10 feet above high-water mark.

'An extensive rocky flat lies around the northern parts of Santa Maria. Before the earthquake this flat was covered by the sea, some projecting rocks only showing themselves. Now, the whole flat is exposed, and square acres of it are covered with dead shell-fish, the stench arising from which is abominable. By this elevation of the land the southern port of Santa Maria has been almost destroyed; little shelter remaining there, and very bad landing.' The surrounding sea is also stated to have become shallower in exactly the same proportion as the land had risen; the soundings having diminished a fathom and a half everywhere around the island.

At Tubal, also, to the south-east of Santa Maria, the land was raised 6 feet, at Mocha 2 feet, but no elevation could be ascertained at Valdivia.

Among other effects of the catastrophe, it is stated that cattle standing on a steep slope, near the shore, were rolled down into the sea, and many others were washed off by the great wave from low land and drowned.*

In November of the same year (1835), Conception was shaken by a severe earthquake, and on the same day Osorno, at the distance of 400 miles, renewed its activity. These facts prove not only the connection of earthquakes with volcanic eruptions in this region, but also the vast extent of the subterranean areas over which the disturbing cause acts simultaneously.

Bay of Naples—Ischia, 1828.—On February 2, the whole

* Darwin's Journ. of Travels in South America, Voyage of 'Beagle, p. 372.

island of Ischia was shaken by an earthquake, and in the October following I found all the houses in Casamicciol still without their roofs. On the sides of a ravine between that town and Forio, I saw masses of greenish tuff which had been thrown down. The hot-spring of Rita, which was nearest the centre of the movement, was ascertained by M. Covelli to have increased in temperature, showing, as he observes, that the explosion took place below the reservoirs which heat the thermal waters.*

Bogota, 1827.—On November 16, 1827, the plain of Bogota, in New Granada, or Colombia, was convulsed by an earthquake, and a great number of towns were thrown down. Torrents of rain swelled the Magdalena, sweeping along vast quantities of mud and other substances, which emitted a sulphurous vapour and destroyed the fish. Popayan, which is distant 200 geographical miles SSW. of Bogota, suffered greatly. Wide crevices appeared in the road of Guanacas, leaving no doubt that the whole of the Cordilleras sustained a powerful shock. Other fissures opened near Costa, in the plains of Bogota, into which the river Tunza immediately began to flow.† Extraordinary rains accompanied the shocks before mentioned; and two volcanos are said to have been in eruption in the mountain-chain nearest to Bogota.

Chili, 1822.—On November 19, 1822, the coast of Chili was visited by a most destructive earthquake. The shock was felt simultaneously throughout a space of 1,200 miles from north to south. St. Jago, Valparaiso, and some other places were greatly injured. When the district round Valparaiso was examined on the morning after the shock, it was found that the coast for a considerable distance was raised above its former level.‡ At Valparaiso, the elevation was 3 feet, and at Quintero about 4 feet. Part of the bed of the sea, says Mrs. Graham, remained bare and dry at high water, 'with beds of oysters, mussels, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia.' §

* Biblioth. Univ. Oct. 1828, p. 175.

† Phil. Mag. July, 1828, p. 37.

‡ Geol. Trans. vol. i. 2nd ser., and Journ. of Sci. 1824, vol. xvii. p. 40.

§ Geol. Trans. vol. i. 2nd ser. p. 415.

An old wreck of a ship, which before could not be approached, became accessible from the land, although its distance from the original sea-shore had not altered. It was observed that the watercourse of a mill, at the distance of about a mile from the sea, gained a fall of 14 inches in little more than 100 yards; and from this fact it is inferred that the rise in some parts of the inland country was far more considerable than on the borders of the ocean.* Part of the coast thus elevated consisted of granite, in which parallel fissures were caused, some of which were traced for a mile and a half inland. Cones of earth about 4 feet high were thrown up in several districts, by the forcing up of water mixed with sand through funnel-shaped hollows,—a phenomenon very common in Calabria, and the explanation of which will hereafter be considered. Those houses in Chili of which the foundations were on rock were less damaged than such as were built on alluvial soil.

Mr. Cruickshanks, an English botanist, who resided in the country during the earthquake, has informed me that some rocks of greenstone at Quintero, a few hundred yards from the beach, which had always been under water till the shock of 1822, have since been uncovered when the tide is at half-ebb; and he states that, after the earthquake, it was the general belief of the fishermen and inhabitants of the Chilian coast, *not* that the land had risen, but that the ocean had permanently retreated.

Dr. Meyen, a Prussian traveller, who visited Valparaiso in 1831, says that on examining the rocks both north and south of the town nine years after the event, he found, in corroboration of Mrs. Graham's account, that remains of animals, and sea-weed, the *Lessonia* of Bory de St. Vincent, which has a firm ligneous stem, still adhered to those rocks which in 1822 had been elevated above high-water mark.† According to the same author, the whole coast of Central Chili was raised about 4 feet, and banks of marine shells were laid dry on many parts of the coast. He observed similar banks, elevated at unknown periods, in several places, especially at

* Journ. of Sci. vol. xvii. p. 42.

† Reise um die Erde; and see Dr. Meyen's letter cited Foreign Quart. Rev. No. 33. p. 18. 1836.

Copiapo, where the species all agree with those now living in the ocean. Mr. Freyer also, who resided some years in South America, has confirmed these statements;* and Mr. Darwin obtained evidence that the remains of an ancient wall, formerly washed by the sea, and now 11½ feet above high-water mark, acquired several feet of this elevation during the earthquake of 1822.†

The shocks continued up to the end of September 1823; even then, 48 hours seldom passed without one, and sometimes two or three were felt during 24 hours. Mrs. Graham observed, after the earthquake of 1822, that besides a beach newly raised above high-water mark, there were several older elevated lines of beach, one above the other, consisting of shingle mixed with shells extending in a parallel direction to the shore, to the height of 50 feet above the sea. ‡

Extent of country elevated.—By some observers it has been supposed that the whole country from the foot of the Andes to a great distance under the sea was upraised in 1822, the greatest rise being at the distance of about 2 miles from the shore. 'The rise upon the coast was from 2 to 4 feet:—at the distance of a mile inland it must have been from 5 to 6 or 7 feet.' § It has also been conjectured by the same eye-witnesses to the convulsion, that the area over which this permanent alteration of level extended may have been equal to 100,000 square miles. Although the increased fall of certain watercourses may have afforded some ground for this conjecture, it must be considered as very hypothetical, and the estimate may have exceeded or greatly fallen short of the truth. It may nevertheless be useful to reflect on the enormous amount of change which this single convulsion occasioned, if the extent of country moved upward really amounted to 100,000 square miles,—an extent just equal to half the area of France, or about five-sixths of the area of Great Britain and Ireland. If we suppose the elevation to have been only 3 feet on an average, it will be seen that the mass of rock added to the continent of America by the move-

* Proc. Geol. Soc. No. xl. p. 179, Feb. 1835.

† Proc. Geol. Soc. vol. ii. p. 447.

‡ Trans. Geol. Soc. vol. i. 2nd ser. p. 415.

§ Journal of Science, vol. xvii. pp. 40, 45.

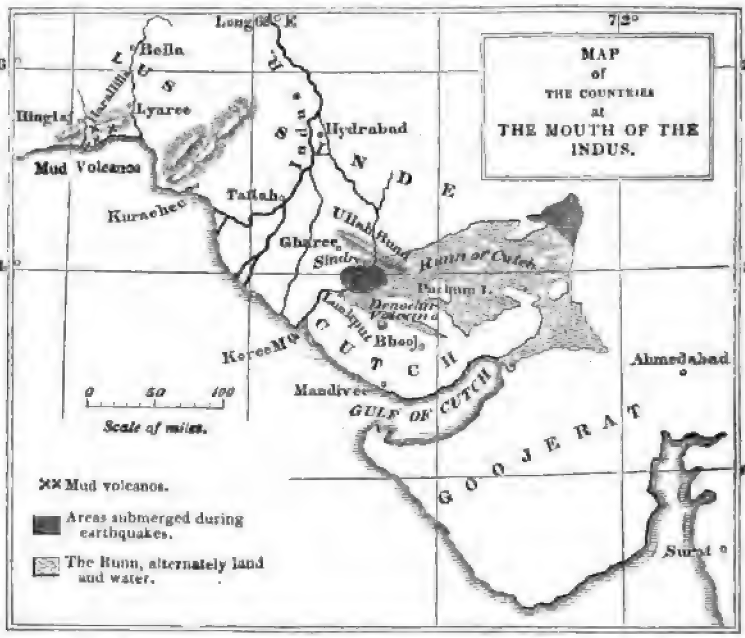
ment, or, in other words, the mass previously below the level of the sea, and after the shocks permanently above it, must have contained 57 cubic miles in bulk ; which would be sufficient to form a conical mountain 2 miles high (or about as high as Etna), with a circumference at the base of nearly 33 miles. We may take the mean specific gravity of the rock at 2·655,—a fair average, and a convenient one in such computations, because at such a rate a cubic yard weighs 2 tons. Then, assuming the Great Pyramid of Egypt, if solid, to weigh, in accordance with an estimate before given, 6,000,000 tons, we may state the rock added to the continent by the Chilian earthquake to have more than equalled 100,000 pyramids.

But it must always be borne in mind that the weight of rock here alluded to constituted but an insignificant part of the whole amount which the volcanic forces had to overcome. The thickness of rock between the surface of Chili and the subterranean foci of volcanic action may be many miles or leagues deep. Say that the thickness was only 2 miles, even then the mass which changed place and rose 3 feet, being 200,000 cubic miles in volume, must have exceeded in weight 363,000,000 pyramids.

It may be instructive to consider these results in connection with others already obtained from a different source, and to compare the working of two antagonist forces—the levelling power of running water, and the expansive energy of subterranean heat. How long, it may be asked, would the Ganges require, according to data before explained from observations made 500 miles up the river, at Ghazepoor (Vol. I. p. 479), to transport to the sea a quantity of solid matter equal to that which may have been added to the land by the Chilian earthquake? The discharge of mud in one year by the Ganges at its mouth (see Vol. I. p. 481) was estimated at 20,000,000,000 cubic feet. According to that estimate it would require about 4 centuries (or 418 years) before the river could bear down from the continent into the sea a mass equal to that gained by the Chilian earthquake. In about half that time, perhaps, the united waters of the Ganges and Burrampooter might accomplish the operation.

Earthquake of Cutch, 1819.—A violent earthquake occurred at Cutch, in the delta of the Indus, on June 16, 1819. (See Map, Fig. 111.) The principal town, Bhooj, was converted into a heap of ruins, and its stone buildings were thrown down. The movement was felt over an area having a radius of 1,000 miles from Bhooj, and extending to Khatmandoo, Calcutta, and Pondicherry.* The vibrations were felt in North-west India, at a distance of 800 miles, after an interval of about 15 minutes after the earthquake at Bhooj. At Ahmedabad the great mosque, erected by Sultan Ahmed nearly 450 years

Fig. 111.



before, fell to the ground, attesting how long a period had elapsed since a shock of similar violence had visited that point. At Anjar, the fort, with its tower and guns, were hurled to the ground in one common mass of ruin. The shocks continued until the 20th; when, 30 miles north-west from Bhooj, the volcano called Denodur is said by some to

* See Asiatic Journal, vol. i.

have sent forth flames, but Captain Grant, when in Cutch in 1838, was unable to authenticate this statement.

Although the ruin of towns was great, the face of nature in the inland country, says Captain (General) Macmurdo, was not visibly altered. In the hills some large masses only of rock and soil were detached from the precipices; but the eastern and almost deserted channel of the Indus, which bounds the province of Cutch, was greatly changed. This estuary, or inlet of the sea, was, before the earthquake, fordable at Luckput, being only about 1 foot deep when the tide was at ebb, and at flood tide never more than 6 feet; but it was deepened at the fort of Luckput, after the shock, to more than 18 *feet at low water.** On sounding other parts of the channel, it was found, that where previously the depth of the water at flood never exceeded 1 or 2 feet, it had become from 4 to 10 feet deep. By these and other remarkable changes of level, a part of the inland navigation of that country, which had been closed for centuries, became again practicable.

Fort and village submerged.—The fort and village of Sindree, on the eastern arm of the Indus, above Luckput, are stated by the same writer to have been overflowed; and, after the shock, the tops of the houses and wall were alone to be seen above the water, for the houses, although submerged, were not cast down (see fig. 113, p. 102). Had they been situated, therefore, in the interior, where so many forts were levelled to the ground, their site would, perhaps, have been regarded as having remained comparatively unmoved. Hence we may suspect that great permanent upheavings and depressions of soil may be the result of earthquakes, without the inhabitants being in the least degree conscious of any change of level.

A more recent survey of Cutch, by Sir A. Burnes, who was not in communication with Captain Macmurdo, confirms the facts above enumerated, and adds many important details.† That officer examined the delta of the Indus in 1826 and 1828, and from his account it appears that, when Sindree subsided in June 1819, the sea flowed in by the eastern

* Macmurdo, Ed. Phil. Journ. iv. 106. This memoir is now in the Library of the Royal Asiatic Society of London.

mouth of the Indus, and in a few hours converted a tract of land, 2,000 square miles in area, into an inland sea, or lagoon. Neither the rush of the sea into this new depression, nor the movement of the earthquake, threw down entirely the small fort of Sindree, one of the four towers, the north-western, still continuing to stand; and, the day after the earthquake,

Fig. 112.

Fort of Sindree, on the eastern branch of the Indus, before it was submerged by the earthquake of 1819, from a sketch by Capt. Grindlay, made in 1808.*

the inhabitants, who had ascended to the top of this tower, saved themselves in boats.†

Elevation of the Ullah Bund.—Immediately after the shock, the inhabitants of Sindree saw at the distance of 5½ miles from their village, a long elevated mound, where previously there had been a low and perfectly level plain. (See Map, p. 98.) To this uplifted tract they gave the name of 'Ullah Bund,' or the 'Mound of God,' to distinguish it from several artificial dams previously thrown across the eastern arm of the Indus.

* I was indebted to my friend the late Sir Alexander Burnes for the accompanying sketch (fig. 112) of the fort of Sindree, as it appeared eleven years before the earthquake.

† Several particulars not given in the earlier edition were afterwards obtained by me from personal communication with Sir. A. Burnes in London.

Extent of country raised.—It has been ascertained that this new-raised country is *upwards of fifty miles* in length from east to west, running parallel to that line of subsidence before mentioned which caused the grounds around Sindree to be flooded. The range of this elevation extends from Puchum Island towards Gharee; its breadth from north to south is conjectured to be in some parts *sixteen miles*, and its greatest ascertained height above the original level of the delta is 10 feet,—an elevation which appears to the eye to be very uniform throughout.

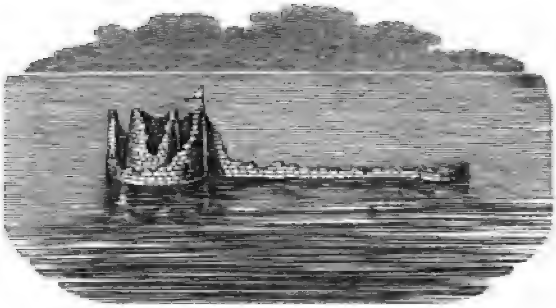
For several years after the convulsion of 1819, the course of the Indus was very unsettled, and at length, in 1826, the river threw a vast body of water into its eastern arm, that called the Phurraun, above Sindree; and forcing its way in a more direct course to the sea, burst through all the artificial dams which had been thrown across its channel, and at length cut right through the 'Ullah Bund,' whereby a natural section was obtained. In the perpendicular cliffs thus laid open Sir A. Burnes found that the upraised lands consisted of clay filled with shells. The new channel of the river where it intersected the 'bund' was 18 feet deep, and 40 yards in width; but in 1828 the channel was still farther enlarged. The Indus, when it first opened this new passage, threw such a body of water into the new mere, or salt lagoon, of Sindree, that it became fresh for many months; but it had recovered its saltness in 1828, when the supply of river-water was less copious, and finally it became more salt than the sea, in consequence, as the natives suggested to Sir A. Burnes, of the saline particles with which the 'Runn of Cutch' is impregnated.

In 1828 Sir A. Burnes went in a boat to the ruins of Sindree, where a single remaining tower was seen in the midst of a wide expanse of sea. The tops of the ruined walls still rose 2 or 3 feet above the level of the water; and standing on one of these, he could behold nothing in the horizon but water, except in one direction, where a blue streak of land to the north indicated the Ullah Bund. This scene presents to the imagination a lively picture of the revolutions now in progress on the earth—a waste of waters where

a few years before all was land, and the only land visible consisting of ground uplifted by a recent earthquake.

Ten years after the visit of Sir A. Burnes above alluded to, my friend Captain Grant, F.G.S., of the Bombay Engineers, had the kindness to send at my request a native surveyor to make a plan of Sindree and the Ullah Bund, in March, 1838. From his description it appears that, at that season, the driest of the whole year, he found the channel traversing the Bund to be 100 yards wide, without water, and encrusted with salt. He was told that it has now only 4 or 5 feet of water in it after rains. The sides or banks were nearly perpendicular, and 9 feet in height. The lagoon has

Fig. 113.



View of the Fort of Sindree, from the west, in March, 1838.

diminished both in area and depth, and part near the fort was dry land. The annexed drawing, made by Captain Grant from the surveyor's plan, shows the appearance of the fort in the midst of the lake, as seen in 1838 from the west or from the same point as that from which Captain Grindlay's sketch (see fig. 112) was taken in 1808, before the earthquake.

The Runn of Cutch is a flat region of a very peculiar character, and no less than 7,000 square miles in area: a greater superficial extent than Yorkshire, or about one-fourth the area of Ireland. It is not a desert of moving sand, nor a marsh, but evidently the dried-up bed of an inland sea, which for a great part of every year has a hard and dry bottom without vegetation or only supporting here and

there a few tamarisks. But during the monsoons, when the sea runs high, the salt-water driven up from the Gulf of Cutch and the creeks at Luckput overflows a large part of the Runn, especially after rains, when the soaked ground permits the sea-water to spread rapidly. The Runn is also liable to be overflowed occasionally in some parts by river-water: and it is remarkable that the only portion which was ever highly cultivated (that anciently called Sayra) is now permanently submerged. The surface of the Runn is sometimes encrusted with salt about an inch in depth, in consequence of the evaporation of the sea-water. Islands rise up in some parts of the waste, and the boundary lands form bays and promontories. The natives have various traditions respecting the former separation of Cutch and Sinde by a bay of the sea, and the drying up of the district called the Runn. But these tales, besides the usual uncertainty of oral tradition, are farther obscured by mythological fictions. The conversion of the Runn into land is chiefly ascribed to the miraculous powers of a Hindoo saint by name Damorath (or Dhoorunnath), who had previously done penance for twelve years on the summit of Denodur hill. Captain Grant infers, on various grounds, that this saint flourished about the 11th or 12th century of our era. In proof of the drying up of the Runn, some towns far inland are still pointed out as having once been ancient ports. It has, moreover, been always said that ships were wrecked and engulphed by the great catastrophe; and in the jets of black muddy water thrown out of fissures in that region, in 1819, there were cast up numerous pieces of wrought iron and ship nails.* Cones of sand 6 or 8 feet in height were at the same time formed on these lands.†

We must not conclude without alluding to a *moral* phenomenon connected with this tremendous catastrophe, which highly deserves the attention of geologists. It is stated by Sir A. Burnes, that 'these wonderful events passed *unheeded* by the inhabitants of Cutch;' for the region convulsed, though once fertile, had for a long period been reduced to sterility by want of irrigation, so that the natives were indifferent as to

* Capt. Burnes' Account.

† Capt. Macmurdo's Memoir, Ed. Phil. Journ. vol. iv. p. 106.

its fate. Now it is to this profound apathy which all but highly civilised nations feel, in regard to physical events not having an immediate influence on their worldly fortunes, that we must ascribe the extraordinary dearth of historical information concerning changes of the earth's surface, which modern observations show to be by no means of rare occurrence in the ordinary course of nature.

Since the above account was written, a description has been published of more recent geographical changes in the district of Cutch, near the mouth of the Koree, or eastern branch of the Indus, which happened in June 1845. A large area seems to have subsided, and the Sindree lake had become a salt marsh.*

Island of Sumbawa, 1815.—In April, 1815, one of the most frightful eruptions recorded in history occurred in the province of Tomboro, in the island of Sumbawa (see Map, fig. 65, Vol. I. p. 587), about 200 miles from the eastern extremity of Java. In April of the preceding year the volcano had been observed in a state of considerable activity, ashes having fallen upon the decks of vessels which sailed past the coast.† The eruption of 1815 began on April 5th, but was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of 970 geographical miles in a direct line; and at Ternate, in an opposite direction, at the distance of 720 miles. Out of a population of 12,000, in the province of Tomboro, only 26 individuals survived. Violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air; tore up the largest trees by the roots, and covered the whole sea with floating timber.‡ Great tracts of land were covered by lava, several streams of which, issuing from the crater of the Tomboro Mountain, reached the sea. So heavy was the fall of ashes, that they broke into the Resident's house at Bima, 40 miles east of the volcano, and rendered it as well as many other dwellings in the town uninhabitable. On the side of Java the ashes were carried to the distance of 300 miles, and 217 towards

* Quart. Geol. Journ. vol. ii. p. 103.

† MS. of J. Crawfurd, Esq.

‡ Raffles's Java, vol. i. p. 28.

Celebes, in sufficient quantity to darken the air. The floating cinders to the westward of Sumbawa formed, on April 12th, a mass 2 feet thick, and several miles in extent, through which ships with difficulty forced their way.

The darkness occasioned in the daytime by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night. Although this volcanic dust when it fell was an impalpable powder, it was of considerable weight when compressed, a pint of it weighing twelve ounces and three-quarters. 'Some of the finest particles,' says Mr. Crawfurd, 'were transported to the islands of Amboyna and Banda, which last is about 800 miles east from the site of the volcano, although the south-east monsoon was then at its height.' They must have been projected, therefore, into the upper regions of the atmosphere, where a counter-current prevailed.

Along the sea-coast of Sumbawa and the adjacent isles, the sea rose suddenly to the height of from 2 to 12 feet, a great wave rushing up the estuaries, and then suddenly subsiding. Although the wind at Bima was still during the whole time, the sea rolled in upon the shore, and filled the lower parts of the houses with water a foot deep. Every prow and boat was forced from the anchorage, and driven on shore.

The town called Tomboro, on the west side of Sumbawa, was overflowed by the sea, which encroached upon the shore so that the water remained permanently 18 feet deep in places where there was land before. Here we may observe, that the amount of subsidence of land was apparent, in spite of the ashes, which would naturally have caused the limits of the coast to be extended.

The tremulous noises and other volcanic effects of this eruption extended over an area 1,000 statute miles in diameter, having Sumbawa as its centre. It included the whole of the Molucca Islands, Java, a considerable portion of Celebes, Sumatra, and Borneo. In the island of Amboyna, in the same month and year, the ground opened, threw out water, and then closed again.*

* Raffles's Hist. of Java, vol. i. p. 25. Ed. Phil. Journ. vol. iii. p. 389.

In conclusion, I may remind the reader, that but for the accidental presence of Sir Stamford Raffles, then governor of Java, we should scarcely have heard in Europe of this tremendous catastrophe. He required all the residents in the various districts under his authority to send in a statement of the circumstances which occurred within their own knowledge; but, valuable as were their communications, they are often calculated to excite rather than to satisfy the curiosity of geologists. They mention, that similar effects, though in a less degree, had, about seven years before, accompanied an eruption of Carang Assam, a volcano in the island of Bali, west of Sumbawa; but no particulars of that great catastrophe are recorded.*

Caraccas, 1812.—On March 26, 1812, several violent shocks of an earthquake were felt in Caraccas. The surface undulated like a boiling liquid, and terrific sounds were heard underground. The whole city with its splendid churches was in an instant a heap of ruins, under which 10,000 of the inhabitants were buried. On April 5, enormous rocks were detached from the mountains. It was believed that the mountain Silla lost from 300 to 360 feet of its height by subsidence; but this was an opinion not founded on any measurement. On April 27, a volcano in St. Vincent's threw out ashes; and, on the 30th, lava flowed from its crater into the sea, while its explosions were heard at a distance equal to that between Vesuvius and Switzerland, the sound being transmitted, as Humboldt supposes, through the ground. During the earthquake which destroyed Caraccas, an immense quantity of water was thrown out at Valecillo, near Valencia, as also at Porto Caballo, through openings in the earth; and in the Lake Maracaybo the water sank. Humboldt observed that the Cordilleras, composed of gneiss and mica slate, and the country immediately at their foot, were more violently shaken than the plains.†

South Carolina and New Madrid, Missouri, 1811-12.—Previous to the destruction of La Guayra and Caraccas, in 1812, earthquakes were felt in South Carolina; and the

* Life and Services of Sir Stamford Raffles, p. 241. London, 1830.

† Humboldt's Pers. Nar. vol. iv. p. 12; and Ed. Phil. Journ. vol. i. p. 272. 1819.

shocks continued till those cities were destroyed. The valley also of the Mississippi, from the village of New Madrid to the mouth of the Ohio in one direction, and to the St. Francis in another, was convulsed in such a degree as to create new lakes and islands. It has been remarked by Humboldt in his Cosmos, that the earthquake of New Madrid presents one of the few examples on record of the incessant quaking of the ground for several successive months *far from any volcano.* Flint, the geographer, who visited the country seven years after the event, informs us, that a tract of many miles in extent, near the Little Prairie, became covered with water 3 or 4 feet deep; and when the water disappeared a stratum of sand was left in its place. Large lakes of 20 miles in extent were formed in the course of an hour, and others were drained. The graveyard at New Madrid was precipitated into the bed of the Mississippi; and it is stated that the ground whereon the town is built, and the river bank for 15 miles above, sank 8 feet below their former level.* The neighbouring forest presented for some years afterwards 'a singular scene of confusion; the trees standing inclined in every direction, and many having their trunks and branches broken.'†

The inhabitants relate that the earth rose in great undulations; and when these reached a certain fearful height, the soil burst, and vast volumes of water, sand, and pit-coal were discharged as high as the tops of the trees. Flint saw hundreds of these deep chasms remaining in an alluvial soil, seven years after. As the shocks lasted throughout a period of three months the country people had time to remark that there were certain prevailing directions in which the fissures opened in their district. Being all of them familiar with the use of the axe, they felled the tallest trees and made them fall at right angles to the direction of the chasms which usually ran from SW. to NE., and by stationing themselves on the trees they often escaped being swallowed up when the earth opened beneath them. At one period during this earthquake,

* Cramer's Navigator, p. 243. Pittsburgh, 1821.

† Long's Exped. to the Rocky Mountains, vol. iii. p. 184.

the ground not far below New Madrid swelled up so as to arrest the Mississippi in its course, and to cause a temporary reflux of its waters. The motion of some of the shocks is described as having been horizontal, and of others perpendicular; and the vertical movement is said to have been much less desolating than the horizontal.

The above account has been reprinted exactly as it appeared in former editions of this work, compiled from the authorities which I have cited; but having more recently (March, 1846) had an opportunity myself of visiting the disturbed region of the Mississippi, and conversing with many eye-witnesses of the catastrophe, I am able to confirm the truth of those statements, and to add some remarks on the present face and features of the country. I skirted, as was before related (Vol. I. p. 453), part of the territory immediately west of New Madrid, called 'the sunk country,' which was for the first time permanently submerged during the earthquake of 1811–12. It is said to extend along the course of the White Water and its tributaries for a distance of between 70 and 80 miles north and south, and 30 miles east and west. I saw on its border many full-grown trees still standing leafless, the bottoms of their trunks several feet under water, and a still greater number lying prostrate. An active vegetation of aquatic plants is already beginning to fill up some of the shallows, and the sediment washed in by occasional floods when the Mississippi rises to an extraordinary height contributes to convert the borders of the sunk region into marsh and forest land. Even on the dry ground along the confines of the submerged area, I observed in some places that all the trees of prior date to 1811 were dead and leafless, though standing erect and entire. They are supposed to have been killed by the loosening of their roots during the repeated undulations which passed through the ground for three months in succession.

Mr. Bringier, an experienced engineer of New Orleans, who was on horseback near New Madrid when some of the severest shocks were experienced, related to me (in 1846), that 'as the waves advanced the trees bent down, and the instant afterwards, while recovering their position, they often

met those of other trees similarly inclined, so that their branches becoming interlocked, they were prevented from righting themselves again. The transit of the wave through the woods was marked by the crushing noise of countless boughs, first heard on one side and then on the other. At the same time powerful jets of water, mixed with sand, mud, and fragments of coaly matter, were cast up, endangering the lives of both horse and rider.'

I was curious to ascertain whether any vestiges still remained of these fountains of mud and water, and carefully examined between New Madrid and the Little Prairie several 'sink holes' as they are termed. They consist of cavities from 10 to 30 yards in width, and 20 feet or more in depth, and are very conspicuous as they interrupt the level surface of a flat alluvial plain. Round their edges I saw abundance of sand, which some of the inhabitants with whom I conversed had seen spouting from these deep holes, also fragments of decayed wood and black bituminous shale, probably drifted down at some former period in the main channel of the Mississippi, from the coal-fields farther north. I also found numerous rents in the soil left by the earthquake, some of them still several feet wide, and a yard or two in depth, although the action of rains, frost, and occasional inundations, and especially the leaves of trees blown into them in countless numbers every autumn, have done much to fill them up. I measured the direction of some of the fissures, which usually varied from 10° to 45° W. of N., and were often parallel to each other; I found, however, a considerable diversity in their direction. Many of them are traceable for half a mile and upwards, but they might easily be mistaken for artificial trenches if resident settlers were not there to assure us that within their recollection they were 'as deep as wells.' Fragments of coaly shale were strewed along the edges of some of these open fissures, together with white sand, in the same manner as round the 'sink holes.'*

Among other monuments of the changes wrought in 1811-12, I explored the bed of a lake called Eulalie, near

* See Lyell's Second Visit to the United States, vol. ii. ch. xxxiii.

New Madrid, 300 yards long by 100 yards in width, which was suddenly drained during the earthquake. The parallel fissures by which the water escaped were not yet entirely closed, and all the trees growing on its bottom were at the time of my visit less than 34 years old. They consisted of cotton-wood, the willow, the honey-locust, and other species, differing from those clothing the surrounding higher grounds, which are more elevated by 12 or 15 feet. On them the hickory, the black and white oak, the gum and other trees, many of them of ancient date, were flourishing.

Reflections on the earthquakes of the nineteenth century.—We are now about to pass on to the events of the eighteenth century: but before we leave the consideration of those already enumerated, let us pause for a moment, and reflect how many remarkable facts of geological interest are afforded by the earthquakes above described, though they constitute but a small part of the convulsions even of half a century. New rocks have risen from the waters; new hot springs have burst out, and the temperature of others has been altered. A large tract in New Zealand has been upraised from 1 to 9 feet above its former level, and another contiguous region depressed several feet, and in the same archipelago a fault or displacement of the rocks nearly 100 miles long and about 9 feet in vertical height has been produced. The coast of Chili has been thrice permanently elevated; a considerable tract in the delta of the Indus has sunk down, and some of its shallow channels have become navigable; an adjoining part of the same district, upwards of 50 miles in length and 16 in breadth, has been raised about 10 feet above its former level; part of the great plain of the Mississippi, for a distance of 80 miles in length by 30 in breadth, has sunk down several feet; the town of Tomboro has been submerged, and 12,000 of the inhabitants of Sumbawa have been destroyed. Yet, with a knowledge of these and other terrific catastrophes, witnessed during so brief a period by the present generation, will the geologist declare with perfect composure that the earth has at length settled into a state of repose? Will he continue to assert that the changes of relative level of land and sea, so common in former ages of the world,

have now ceased? If, in the face of so many striking facts, he persists in maintaining this favourite dogma, it is in vain to hope that, by accumulating the proofs of similar convulsions during a series of antecedent ages, we shall shake his tenacity of purpose:—

> Si fractus illabatur orbis,
> Impavidum ferient ruinæ.

CHAPTER XXIX.

EARTHQUAKES OF THE EIGHTEENTH CENTURY—QUITO, 1797—SICILY, 1790—CALABRIA, FEBRUARY 5, 1783—SHOCKS CONTINUED TO THE END OF THE YEAR 1786—AUTHORITIES—AREA CONVULSED—GEOLOGICAL STRUCTURE OF THE DISTRICT—MOVEMENT IN THE STONES OF TWO OBELISKS—BOUNDING OF DETACHED MASSES INTO THE AIR—DIFFICULTY OF ASCERTAINING CHANGES OF LEVEL—SUBSIDENCE OF THE QUAY AT MESSINA—SHIFT OR FAULT IN THE ROUND TOWER OF TERRANUOVA—OPENING AND CLOSING OF FISSURES—LARGE EDIFICES ENGULPHED—DIMENSIONS OF NEW CAVERNS AND FISSURES—GRADUAL CLOSING IN OF RENTS—DERANGEMENT OF RIVER COURSES—LANDSLIPS—BUILDINGS TRANSPORTED ENTIRE TO GREAT DISTANCES—NEW LAKES—FUNNEL-SHAPED HOLLOWS IN ALLUVIAL PLAINS—CURRENTS OF MUD—FALL OF CLIFFS, AND SHORE NEAR SCILLA INUNDATED—STATE OF STROMBOLI AND ETNA DURING THE SHOCKS—ORIGIN AND MODE OF PROPAGATION OF EARTHQUAKE WAVES—DEPTH OF THE SUBTERRANEAN SOURCE OF THE MOVEMENT—NUMBER OF PERSONS WHO PERISHED DURING THE EARTHQUAKE OF 1783—CONCLUDING REMARKS.

THE earthquakes of the 18th century which we have next to consider are so numerous that a few of them only can be mentioned. I shall select therefore such as are peculiarly illustrative of geological changes, treating of the more modern events first, and then of the others in retrospective order, according to the plan observed in the last chapter for reasons there explained.

Quito, 1797.—The convulsion of this year in Quito was remarkable for the extent of country shaken, and for the alterations caused in river courses, and still more for the floods of 'moya' or fetid mud which issued from the crater of the volcano of Tunguragua.*

Caraccas, 1790.—During an earthquake in Caraccas in 1790 the granitic soil on which the forest of Aripao grew, is said to have sunk, giving rise to a lake 800 yards in diameter, and from 80 to 100 feet in depth. The trees remained green for several months under water.

* Cavanilles, Journ. de Phys., tome xlix. p. 230. Gilbert's Annalen, bd. vi. Humboldt's Voy. p. 317.

Sicily, 1790.—Ferrara informs us that in Sicily in the same year (1790) at Santa Maria di Niscemi, some miles from Terranuova, near the south coast, the ground sank down during 7 shocks for a circumference of about 3 miles, and to the depth in one place of 30 feet. The subsidence continued for a month, and several fissures sent forth sulphur, petroleum, steam and hot water, and a stream of mud flowed out of one of them. The strata where this happened consisted of blue clay, and the site is far distant from the region both of ancient and modern volcanos in Sicily.*

Java, 1786.—During an earthquake in 1786 at Batur in Java which was followed by a volcanic eruption, the river Dotog entered one of several newly-formed rents, and continued after the shocks to pursue a subterranean course. This fact, noticed by contemporary writers, was afterwards verified by Dr. Horsfield.

EARTHQUAKE OF CALABRIA, 1783.

Of all the subterranean convulsions of the last century, that of Calabria in 1783 is almost the only one which has been so circumstantially described as materially to aid the geologist in appreciating the changes in the earth's crust which a repetition of similar events must produce in the lapse of ages. The shocks began in February of that year, and lasted for nearly 4 years, to the end of 1786. Neither in duration, nor in violence, nor in the extent of territory moved, was this convulsion remarkable, when contrasted with many experienced in other countries, both during the last and present century; nor were the alterations which it occasioned in the relative level of hill and valley, land and sea, so great as those effected by some subterranean movements in South America, in later times. The importance of the earthquake in question arises from the circumstance, that Calabria affords the first example of a region visited, both during and after the convulsions, by men possessing sufficient leisure, zeal, and scientific information to enable them to collect and describe with accuracy such physical facts as throw light on geological questions.

* Ferrara, Campi Fleg. p. 51.

Authorities.—Among the numerous authorities, Vivenzio, physician to the King of Naples, transmitted to the court a regular statement of his observations during the continuance of the shocks; and his narrative is drawn up with care and clearness.* Francesco Antonio Grimaldi, then secretary of war, visited the different provinces at the King's command, and published a most detailed description of the permanent changes in the surface.† He measured the length, breadth, and depth of the different fissures and gulphs which opened,

Fig. 114.

Map of part of Calabria shaken by the earthquake of 1783.

and ascertained their number in many provinces. His comments, moreover, on the reports of the inhabitants, and his explanations of their relations, are judicious and instructive. Pignataro, a physician residing at Monteleone, a town placed in the very centre of the convulsions, kept a register of the

* Istoria de' Tremuoti della Calabria del 1783.

† Descriz. de' Tremuoti Accad. nelle Calabria nel 1783. Napoli, 1784.

shocks, distinguishing them into four classes, according to their degree of violence. From his work, it appears that, in the year 1783, the number was 949, of which 501 were shocks of the first degree of force; and in the following year there were 151, of which 98 were of the first magnitude.

Count Ippolito, also, and many others, wrote descriptions of the earthquake; and the Royal Academy of Naples, not satisfied with these and other observations, sent a deputation from their own body into Calabria, before the shocks had ceased, who were accompanied by artists instructed to illustrate by drawings the physical changes of the district, and the state of ruined towns and edifices. Unfortunately these artists were not very successful in their representations of the condition of the country, particularly when they attempted to express, on a large scale, the extraordinary revolutions which many of the great and minor river-courses underwent. But some of the plates published by the Academy are valuable; and as they are little known, I shall frequently avail myself of them to illustrate the facts about to be described.*

In addition to these Neapolitan sources of information, our countryman, Sir William Hamilton, surveyed the district, not without some personal risk, before the shocks had ceased; and his sketch, published in the Philosophical Transactions, supplies many facts that would otherwise have been lost. He has explained, in a rational manner, many events which, as related in the language of some eye-witnesses, appeared marvellous and incredible. Dolomieu also examined Calabria during the catastrophe, and wrote an account of the earthquake, correcting a mistake into which Hamilton had fallen, who supposed that a part of the tract shaken had consisted of volcanic tuff. It is, indeed, a circumstance which enhances the geological interest of the commotions which so often modify the surface of Calabria, that they are confined to a country where there are neither ancient nor modern rocks of volcanic or trappean origin; so that at some future time, when the era of disturbance shall have passed by, the cause of former revolutions will be

* Istoria de' Fenomeni del Tremoto, &c. nell' An. 1783, posta in luce dalla Real. Accad. &c. di Nap. Napoli, 1783, fol.

as latent as in parts of Great Britain now occupied exclusively by ancient marine formations.

Extent of the area convulsed.—The convulsion of the earth, sea, and air extended over the whole of Calabria Ultra, the south-east part of Calabria Citra, and across the sea to Messina and its environs; a district lying between the 38th and 39th degrees of latitude. The concussion was perceptible over a great part of Sicily, and as far north as Naples; but the surface over which the shocks acted so forcibly as to excite intense alarm did not generally exceed 500 square miles in area. That part of Calabria is composed chiefly, like the southern part of Sicily, of argillaceous strata of great thickness, containing marine shells, sometimes associated with beds of sand and limestone. For the most part these formations resemble in appearance and consistency the Subapennine marls, with their accompanying sands and sandstones; and the whole group bears considerable resemblance, in the yielding nature of its materials, to most of our tertiary deposits in France and England. Chronologically considered, however, the Calabrian formations are comparatively of modern date, often abounding in fossil shells referable to species now living in the Mediterranean.

We learn from Vivenzio that on the 20th and 26th of March, 1783, earthquakes occurred in the Ionian Islands, Zante, Cephalonia, and St. Maura; and in the last-mentioned island several public edifices and private houses were overthrown, and many people destroyed.

If the city of Oppido, in Calabria Ultra, be taken as a centre, and round that centre a circle be described, with a radius of 22 miles, this space will comprehend the surface of the country which suffered the greatest alteration, and where all the towns and villages were destroyed. The first shock, of February 5, 1783, threw down, in two minutes, the greater part of the houses in all the cities, towns, and villages, from the western flanks of the Apennines in Calabria Ultra to Messina in Sicily, and convulsed the whole surface of the country. Another occurred on March 28, with almost equal violence. The granitic chain which passes through Calabria from north to south, and attains the height of many thousand

feet, was shaken but slightly by the first shock, but more rudely by some which followed.

Some writers have asserted that the wave-like movements which were propagated through the recent strata, from west to east, became very violent when they reached the point of junction with the granite, as if a reaction was produced where the undulatory movement of the soft strata was suddenly arrested by the more solid rocks. But the statement of Dolomieu on this subject is the most interesting, and perhaps, in a geological point of view, the most important of all the observations which are recorded.* The Apennines, he says, which consist in great part of hard and solid granite, with some micaceous and argillaceous schists, form bare mountains with steep sides, and exhibit marks of great degradation. At their base newer strata are seen of sand and clay, mingled with shells; a marine deposit containing such ingredients as would result from the decomposition of granite. The surface of this newer (*tertiary*) formation constitutes what is called the plain of Calabria—a platform which is flat and level, except where intersected by narrow valleys or ravines, which rivers and torrents have excavated sometimes to the depth of 600 feet. The sides of these ravines are almost perpendicular; for the superior stratum, being bound together by the roots of trees, prevents the formation of a sloping bank. The usual effect of the earthquake, he continues, was to disconnect all those masses which either had not sufficient bases for their bulk, or which were supported only by lateral adherence. Hence it follows that throughout the whole length of the chain, the soil which adhered to the granite at the base of the mountains Caulone, Esope, Sagra, and Aspromonte, slid over the solid and steeply inclined nucleus, and descended somewhat lower, leaving almost uninterruptedly from St. George to beyond St. Christina, a distance of from 9 to 10 miles, a chasm between the solid granitic nucleus and the sandy soil. Many lands slipping thus were carried to a considerable distance from their former position, so as entirely to cover

* Dissertation on the Calabrian Earthquake, &c., translated in Pinkerton's Voyages and Travels, vol. v.

others; and disputes arose as to whom the property which had thus shifted its place should belong.

From this account of Dolomieu we might anticipate, as the result of a continuance of such earthquakes, first, a longitudinal valley following the line of junction of the older and newer rocks; secondly, greater disturbance in the newer strata near the point of contact than at a greater distance from the mountains; phenomena very common in other parts of Italy at the junction of the Apennine and Subapennine formations.

Mr. Mallet, in his valuable essay on the Dynamics of Earthquakes,* offers the following explanation of the fact to which Dolomieu has called attention. When a wave of elastic compression, of which he considers the earth-wave to consist, passes abruptly from a body having an extremely low elasticity, such as clay and gravel, into another like granite, whose elasticity is remarkably high, it changes not only its velocity but in part also its course, a portion being reflected and a portion refracted. The wave being thus sent back again produces a shock in the opposite direction, doing great damage to buildings on the surface by thus returning upon itself. At the same time, the shocks are at once eased when they get into the more elastic materials of the granitic mountains.

The surface of the country during the Calabrian earthquakes often heaved like the billows of a swelling sea, which produced a swimming in the head, like sea-sickness. It is particularly stated, in almost all the accounts, that just before each shock the clouds appeared motionless; and, although no explanation is offered of this phenomenon, it seems obviously the same as that observed in a ship at sea when it pitches violently. The clouds seem arrested in their career as often as the vessel rises in a direction contrary to their course; so that the Calabrians must have experienced precisely the same motion on the land.

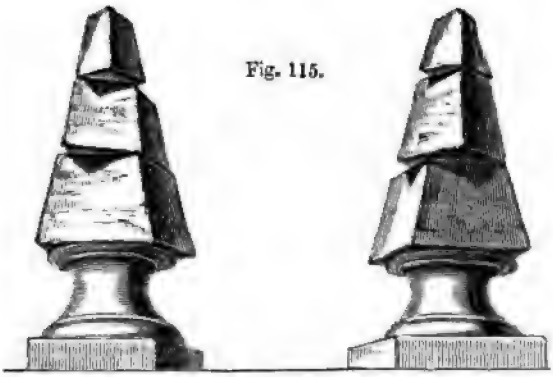
Trees, supported by their trunks, sometimes bent during the shocks to the earth, and touched it with their tops. This

* Proceed. Roy. Irish Acad. 1846, p. 26.

is mentioned as a well-known fact by Dolomieu; and he assures us that he was always on his guard against the spirit of exaggeration in which the vulgar are ever ready to indulge when relating these wonderful occurrences.

The reader must not suppose that these waves, although described as passing along the solid surface of the earth in a given direction like a billow on the sea, have any strict analogy with the undulations of a fluid. They must be regarded as the effects of vibrations, radiating from some deep-seated point, each vibration on reaching the surface lifting up the ground, and then allowing it again to subside. The manner in which the vibratory jar reaches different points of the surface in succession according to the outline of the country, will be explained in the sequel. (See p. 136.)

Fig. 115.



Shifts in the stones of two obelisks in the Convent of S. Bruno.

The Academicians described derangements in some of the buildings of Calabria which seemed to them to indicate a whirling or vorticose movement. Thus, for example, two obelisks (fig. 115) placed at the extremities of a magnificent façade in the convent of S. Bruno, in a small town called Stefano del Bosco, were observed to have undergone a movement of a singular kind. The shock which agitated the building is described as having been horizontal and vorticose. The pedestal of each obelisk remained in its original place; but the separate stones above were turned partially round, and removed sometimes nine inches from their position without falling.

It has been suggested by Mr. Darwin, that this kind of displacement may be due to a vibratory rather than a whirling motion;* and more lately Mr. Mallet, in the paper already cited, has offered a satisfactory solution of the problem. He refers the twisting simply to an elastic wave, which has moved the pedestal forwards and back again, by an alternate horizontal motion within narrow limits; and he has succeeded in showing that a rectilinear movement in the ground may have sufficed to cause an incumbent body to turn partially round upon its bed, provided a certain relation exist between the position of the centre of gravity of the body and its centre of adherence.†

The violence of the movement of the ground upwards was singularly illustrated by what the Academicians call the 'sbalzo,' or bounding into the air, to the height of several yards, of masses slightly adhering to the surface. In some towns a great part of the pavement stones were thrown up, and found lying with their lower sides uppermost. In these cases, we must suppose that they were propelled upwards by the momentum which they had acquired; and that the adhesion of one end of the mass being greater than that of the other, a rotatory motion had been communicated to them. When the stone was projected to a sufficient height to perform somewhat more than a quarter of a revolution in the air, it pitched down on its edge, and fell with its lower side uppermost.

New fissures and changes of level.—I shall now consider, in the first place, those changes which are connected with the rending and fissuring of rocks or with alterations in the relative level of the different parts of the land; and afterwards describe those which are more immediately connected with the derangement of the regular drainage of the country, and where the force of running water cooperated with that of the earthquake.

In regard to alterations of relative level, none of the accounts establish that they were on a considerable scale; but it must always be remembered that, in proportion to the area moved is the difficulty of proving that the general level

* Journal of a Naturalist, p. 376 and ii. ib. 308.

† Proceedings Roy. Irish Acad. 1846, pp. 14–16.

has undergone any change, unless the sea-coast happens to have participated in the principal movement. Even then it is often impossible to determine whether an elevation or depression even of several feet has occurred, because there is nothing to attract notice in a band of shingle and sand of unequal breadth above the level of the sea running parallel to a coast; such bands generally marking the point reached by the waves during spring tides, or the most violent tempests. The scientific investigator has not sufficient topographical knowledge to discover whether the extent of beach has diminished or increased; and he who has the necessary local information scarcely ever feels any interest in ascertaining the amount of the rise or fall of the ground. Add to this the great difficulty of making correct observations, in consequence of the enormous waves which roll in upon a coast during an earthquake, and efface every landmark near the shore.

It is evidently in seaports alone that we can look for very accurate indications of slight changes of level; and when we find them, we may presume that they would not be rare at other points, if equal facilities of comparing relative altitudes were afforded. Grimaldi states (and his account is confirmed by Hamilton and others), that at Messina, in Sicily, the shore was rent; and the soil along the port, which before the shock was perfectly level, was found afterwards to be inclined towards the sea,—the sea itself near the 'Branchia' becoming deeper, and its bottom in several places disordered. The quay also sunk down about 14 inches below the level of the sea, and the houses in its vicinity were much fissured.*

Unfortunately we are without data for determining whether these changes were superficial only, and due to the sliding down or settling of the soil, or whether they were connected with deep-seated movements altering the relative level of sea and land.

Among various proofs of partial elevation and depression in the interior, the Academicians mention, in their Survey, that the ground was sometimes on the same level on both sides of new ravines and fissures, but sometimes there had

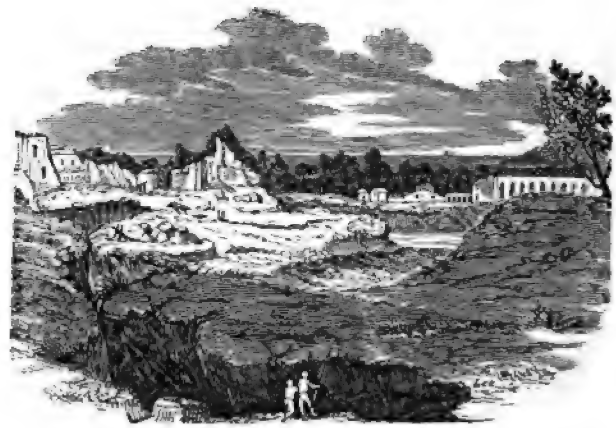
* Phil. Trans. 1783.

been a considerable upheaving of one side, or subsidence of the other. Thus, on the sides of long rents in the territory of Soriano, the stratified masses had altered their relative position to the extent of from 8 to 14 palms (6 to 10½ feet).

Similar shifts in the strata are alluded to in the territory of Polistena, where there appeared innumerable fissures in the earth. One of these was of great length and depth; and in parts the level of the corresponding sides was greatly changed. (See fig. 116.)

In the town of Terranuova some houses were seen uplifted above the common level, and others adjoining sunk down into the earth. In several streets the soil appeared thrust

Fig. 116.



Deep fissure, near Polistena, caused by the earthquake of 1783.

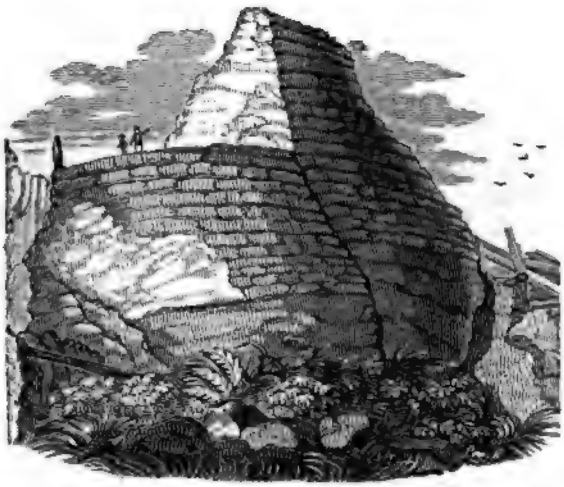
up, and abutted against the walls of houses: a large circular tower of solid masonry, part of which had withstood the general destruction, was divided by a vertical rent, and one side was upraised, and the foundations heaved out of the ground. It was compared by the Academicians to a great tooth half extracted from the alveolus, with the upper part of the fangs exposed. (See fig. 117.)

Along the line of this shift, or 'fault,' the walls were found to adhere firmly to each other, and to fit so well, that the only sign of their having been disunited was the want of correspondence in the courses of stone on either side of the rent.

Dolomieu saw a stone well in a convent of the Augustins at Terranuova, which had the appearance of having been driven out of the earth. It resembled a small tower 8 or 9 feet in height, and a little inclined. This effect, he says, was produced by the consolidation and consequent sinking of the sandy soil in which the well was dug.

In some walls which had been thrown down, or violently shaken, in Monteleone, the separate stones were parted from the mortar, so as to leave an exact mould where they had rested; whereas in other cases the mortar was ground to dust between the stones.

Fig. 117.



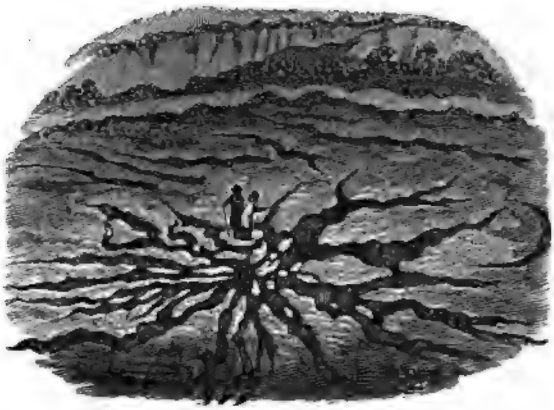
Shift or 'fault' in the Round Tower of Terranuova in Calabria, occasioned by the earthquake of 1783.

It appears that the wave-like motions often produced effects of the most capricious kind. Thus, in some streets of Monteleone, every house was thrown down but one; in others, all but two; and the buildings which were spared were often scarcely in the least degree injured. In many cities of Calabria, all the most solid buildings were thrown down, while those which were slightly built escaped; but at Rosarno, as also at Messina in Sicily, it was precisely the reverse, the massive edifices being the only ones that stood.

As the earthquake-wave passed along the surface of the ground, rents and chasms opened and closed alternately, so

that houses, trees, cattle and men were first engulphed in an instant, and then the sides of the fissures coming together again no vestige of them was to be seen on the surface. We may conceive the same effect to be produced on a small scale, if, by some mechanical force, a pavement composed of large flags of stone should be raised up, and then allowed to fall suddenly, so as to resume its original position. If any small pebbles happened to be lying on the line of contact of two flags, they would fall into the opening when the pavement rose, and be swallowed up, so that no trace of them would appear after the subsidence of the stones. In many instances, individuals are said to have been swallowed up by one shock,

Fig. 118.



Fissures near Jerocarne, in Calabria, caused by the earthquake of 1783.

and then thrown out again alive, together with large jets of water, by the shock which immediately succeeded.

At Jerocarne, a country which, according to the Academicians, was *lacerated* in a most extraordinary manner, the fissures ran in every direction 'like cracks on a broken pane of glass.' (See fig. 118.)

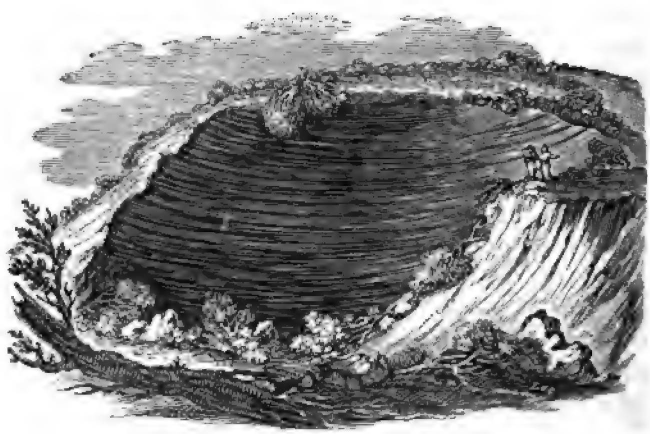
As we learn from Dolomieu that the direction of the new chasms and fissures throughout Calabria was usually parallel to the course of ravines and gorges pre-existing in their neighbourhood, we may conclude that not a few of them were due to a comparatively superficial movement of the ground in a sideway direction.

In the vicinity of Oppido, the central point where the shocks of the earthquake were most violent, many houses were swallowed up by the yawning earth, which closed immediately over them. In the adjacent district, also, of Cannamaria four farm-houses, several oil-stores, and some spacious dwelling-houses were so completely engulphed in one chasm, that not a vestige of them was afterwards discernible. The same phenomenon occurred at Terranuova, S. Christina, and Sinopoli. The Academicians state particularly, that when deep abysses had opened in the argillaceous strata of Terranuova, and houses had sunk into them, the sides of the chasms closed with such violence, that, on excavating afterwards to recover articles of value, the workmen found the contents and detached parts of the buildings jammed together so as to become one compact mass.

Sir W. Hamilton was shown several deep fissures in the vicinity of Mileto, which, although not one of them was above a foot in breadth, had opened so wide during the earthquake as to swallow an ox and nearly one hundred goats. The Academicians also found, on their return through districts which they had passed at the commencement of their tour, that many rents had, in that short interval, gradually closed in, so that their width had diminished several feet, and the opposite walls had sometimes nearly met. It is natural that this should happen in argillaceous strata, while, in more solid rocks, we may expect that fissures will remain open for ages. Should this be ascertained to be a general fact in countries convulsed by earthquakes, it may afford a satisfactory explanation of a common phenomenon in mineral veins. Such veins often retain their full size so long as the rocks consist of limestone, granite, or other indurated materials; but they contract their dimensions, become mere threads, or are even entirely cut off, where masses of an argillaceous nature are interposed. If we suppose the filling up of fissures with metallic and other ingredients to be a process requiring ages for its completion, it is obvious that the opposite walls of rents, where strata consist of yielding materials, must collapse or approach very near to each other before sufficient time is allowed for the accretion of a large quantity of veinstone.

Some of the chasms which opened seem to imply the sinking down of the earth into subterranean cavities. One of these was observed by the Academicians on the sloping

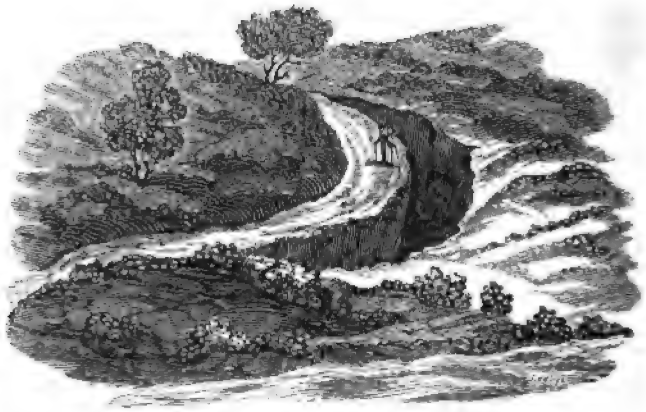
Fig. 119.



Chasm formed by the earthquake of 1783 near Oppido, in Calabria.

side of a hill near Oppido, into which part of a vineyard and a considerable number of olive trees with a large quantity of soil were precipitated. Yet a great gulf remained after the

Fig. 120.



Chasm in the hill of St. Angelo, near Soriano, in Calabria, caused by the earthquake of 1783.

shock, in the form of an amphitheatre, 500 feet long and 200 feet deep. (See fig. 119.)

According to Grimaldi, many fissures and chasms, formed by the first shock of February 5th, were greatly widened, lengthened, and deepened by the violent convulsions of March 28th. Some of these were nearly a mile in length, and from 150 to more than 200 feet in depth, usually straight, but some of them in the form of a crescent. The annexed cut (fig. 120) represents one by no means remarkable for its dimensions, which remained open by the side of a small pass over the hill of St. Angelo, near Soriano. The small river Mesima is seen in the foreground.

Formation of circular hollows and new lakes.—In the report of the Academy, we find that some plains were covered with

Fig. 121.

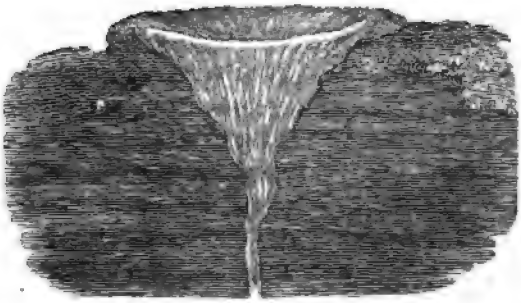
Circular hollows in the plain of Rosarno, formed by the earthquake of 1783.

circular hollows, for the most part about the size of carriage-wheels, but often somewhat larger or smaller. When filled with water to within a foot or two of the surface, they appeared like wells; but, in general, they were filled with dry sand, sometimes with a concave surface, and at other times convex. (See fig. 121.) On digging down, they found them to be funnel-shaped, and the moist loose sand in the centre marked the tube up which the water spouted. The annexed cut (fig. 122) represents a section of one of these

inverted cones when the water had disappeared, and nothing but dry micaceous sand remained.

A small circular pond of similar character was formed not far from Polistena (see fig. 123); and in the vicinity of Seminara, a lake was suddenly caused by the opening of a great chasm, from the bottom of which water issued. This

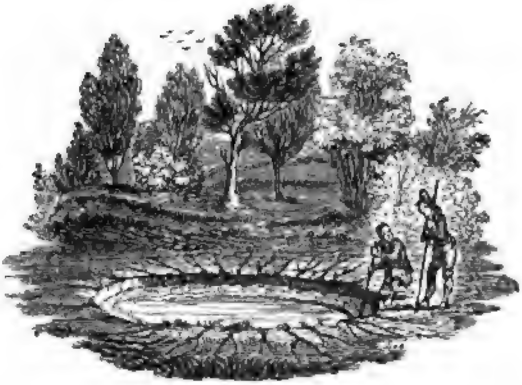
Fig. 122.



Section of one of the circular hollows formed in the plain of Rosarno.

lake was called Lago del Tolfilo. It extended 1,785 feet in length, by 937 in breadth, and 52 in depth. The inhabitants, dreading the miasma of this stagnant pool, endeavoured, at

Fig. 123.



Circular pond near Polistena in Calabria, caused by the earthquake in 1783.

great cost, to drain it by canals, but without success, as it was fed by springs issuing from the bottom of the deep chasm.

Cones of sand thrown up.—Many of the appearances ex-

hibited in the alluvial plains, such as springs spouting up their water like fountains at the moment of the shock, have been supposed to indicate the alternate rising and sinking of the ground. The first effect of the more violent shocks was usually to dry up the rivers, but they immediately afterwards overflowed their banks. In marshy places, an immense number of cones of sand were thrown up. These appearances Hamilton explains, by supposing that the first movement raised the fissured plain from below upwards, so that the rivers and stagnant waters in bogs sank down, or at least were not upraised with the soil. But when the ground returned with violence to its former position, the water was thrown up in jets through fissures.

The phenomenon, according to Mr. Mallet, may be simply an accident contingent on the principal cause of disturbance, the rapid transit of the earth-wave. 'The sources,' he says, 'of copious springs usually lie in flat plates or fissures filled with water, whether issuing from solid rock, or from loose materials; now, if a vein, or thin flat cavity filled with water, be in such a position that the plane of the plate of water or fissure be transverse to the line of transit of the earth-wave, the effect of the arrival of the earth-wave at the watery fissure will be, at the instant, to compress its walls more or less together, and so squeeze out the water, which will, for a moment, gush up at the springhead like a fountain, and again remain in repose after the transit of the wave.'

Derangement of river-courses.—Vivenzio states, that near Sitizzano a valley was nearly filled up to a level with the high grounds on each side, by the enormous masses detached from the boundary hills, and cast down into the course of two streams. By this barrier a lake was formed of great depth, about 2 miles long and 1 mile broad. The same author mentions that, upon the whole, there were 50 lakes occasioned during the convulsions: and he assigns localities to all of these. The government surveyors enumerated 215 lakes; but they included in this number many small ponds.

Such lakes and ponds could only be permanent where rivers and brooks were diverted into an entirely new course, whether into some adjoining ravine or into a different part of the

same alluvial plain. In cases where the new barrier obstructs the whole of the drainage, the water flowing over the dam will gradually deepen a new channel in it, and drain the lake.*

From each side of the deep valley or ravine of Terranuova, enormous masses of the adjoining flat country were detached, and cast down into the course of the river, so as to give rise to lakes. Oaks, olive-trees, vineyards, and corn, were often seen growing at the bottom of the ravine, as little injured as their former companions, which still continued to flourish in the plain above, at least 500 feet higher, and at the distance of about ¾ of a mile. In one part of this ravine was a mass, 200 feet high and about 400 feet circumference at its base, which had been detached by some former earthquake. It is well attested, that this mass travelled down the ravine nearly 4 miles, having been put in motion by the earthquake of February 5. Hamilton, after examining the spot, declared that this phenomenon might be accounted for by the declivity of the valley, the great abundance of rain which fell, and the great weight of the alluvial matter which pressed behind it. Dolomieu also alludes to the fresh impulse derived from other masses falling, and pressing upon the rear of those first set in motion.

The first account sent to Naples of the two great slides or landslips above alluded to, which caused a great lake near Terranuova, was couched in these words:—'Two mountains on the opposite sides of a valley walked from their original positions until they met in the middle of the plain, and there joining together, they intercepted the course of a river,' &c. The expressions here used resemble singularly those applied to phenomena, probably very analogous, which are said to have occurred at Fez, during the great Lisbon earthquake, as also in Jamaica and Java at other periods.

Not far from Soriano, the houses of which were levelled to the ground by the great shock of February, a small valley, containing a beautiful olive-grove, called Fra Ramondo, underwent a most extraordinary revolution. Innumerable fissures first traversed the river-plain in all directions, and

* See Robert Mallet, Neapolitan Earthquake of 1857, vol. ii. p. 372.

absorbed the water until the argillaceous substratum became soaked, so that a great part of it was reduced to a state of fluid paste. Strange alterations in the outline of the ground were the consequence, as the soil to a great depth was easily moulded into any form. In addition to this change, the ruins of the neighbouring hills were precipitated into the hollow; and while many olives were uprooted, others remained growing on the fallen masses, and inclined at various angles. (See fig. 124.) The small river Caridi was entirely concealed for many days; and when at length it reappeared, it had shaped for itself a new channel.

Near Seminara an extensive olive-ground and orchard were

Fig. 124.

Changes of the surface at Fra Ramondo, near Soriano, in Calabria.

1. Portion of a hill covered with olives thrown down.
2. New bed of the river Caridi.
3. Town of Soriano.

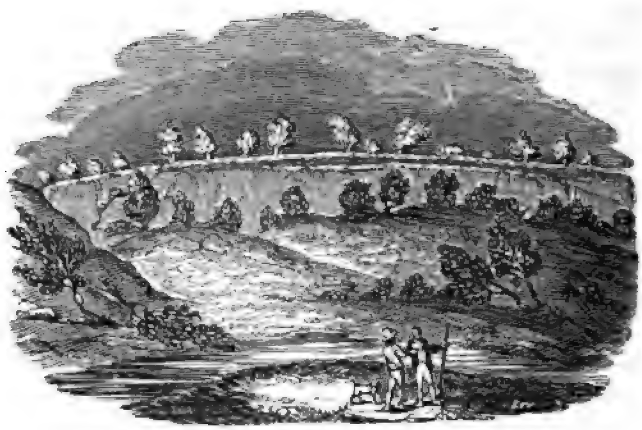
hurled to a distance of 200 feet, into a valley 60 feet in depth. At the same time a deep chasm was riven in another part of the high platform from which the orchard had been detached, and the river immediately entered the fissure, leaving its former bed completely dry. A small inhabited house, standing on the mass of earth carried down into the valley, went along with it entire, and without injury to the inhabitants. The olive-trees, also, continued to grow on the land which

had slid into the valley, and bore the same year an abundant crop of fruit.

Two tracts of land on which a great part of the town of Polistena stood, consisting of some hundreds of houses, travelled into a contiguous ravine, and nearly across it, about half a mile from their original site; and what is most extraordinary, several of the inhabitants were dug out from the ruins alive and unhurt.

Two tenements, near Mileto, called the Macini and Vaticano, occupying an extent of ground about 1 mile long and ½ a mile broad, were carried for 1 mile down a valley. A thatched cottage, together with large olive and mulberry trees, most of which remained erect, were carried uninjured to this extraordinary distance. According to Hamilton, the surface removed had been long undermined by rivulets, which

Fig. 125.



Landslips near Cinquefrondi, caused by the earthquake of 1783.

were afterwards in full view on the bare spot deserted by the tenements. The earthquake seems to have opened a passage in the adjoining argillaceous hills, which admitted water charged with loose soil into the subterranean channels of the rivulets immediately under the tenements, so that the foundations of the ground set in motion by the earthquake were loosened. An example of subsidence, where the edifices were not destroyed, is mentioned by Grimaldi, as having

taken place in the city of Catanzaro, the capital of the province of that name. The houses in the quarter called San Giuseppe subsided with the ground to various depths from 2 to 4 feet, but the buildings remained uninjured. Among other territories, that of Cinquefrondi was greatly convulsed, various portions of soil being raised or sunk, and innumerable fissures traversing the country in all directions (see fig. 125). Along the flanks of a small valley in this district there appears to have been an almost uninterrupted line of landslips.

Near S. Lucido, among other places, the soil is described as having been 'dissolved,' so that large torrents of mud inundated all the low grounds, like lava. Just emerging from this mud, the tops only of trees and of the ruins of farm-houses were seen. Two miles from Laureana, the swampy soil in two ravines became filled with calcareous matter, which oozed out from the ground immediately before the first great shock. This mud, rapidly accumulating, began, ere long, to roll onward, like a flood of lava, into the valley, where the two streams uniting, moved forward with increased impetus from east to west. It now presented a breadth of 225 feet by 15 in depth, and, before it ceased to move, covered a surface equal in length to an Italian mile. In its progress it overwhelmed a flock of 30 goats, and tore up by the roots many olive and mulberry trees, which floated like ships upon its surface. When this calcareous lava had ceased to move, it gradually became dry and hard, during which process the mass was lowered 7½ feet. It contained fragments of earth of a ferruginous colour, and emitting a sulphureous smell.

If our space permitted, we might fill a volume with local details of landslips, which the different authors above alluded to supply, showing to how great an extent the power of rivers to widen valleys is increased where earthquakes are of periodical occurrence. A geologist can never fully understand the manner in which valleys have been formed until he duly appreciates the part which subterranean movements repeated at long intervals play in combination with rivers, during that lapse of ages which must always be required for

the elevation of a country to the height of many hundreds of feet above the level of the sea.

Time must be allowed in the intervals between distinct convulsions, for running water to clear away the ruins caused by landslips, otherwise the fallen masses will serve as buttresses, and prevent the succeeding earthquake from exerting its full power. The sides of the valley must be again cut away by the stream, and made to form precipices and overhanging cliffs, before the next shock can take effect in the same manner.

Fall of the sea-cliffs.—Along the sea-coast of the Straits of Messina, near the celebrated rock of Scilla, the fall of huge masses detached from the bold and lofty cliffs overwhelmed many villas and gardens. At Gian Greco, a continuous line of cliff, for a mile in length, was thrown down. Great agitation was frequently observed in the bed of the sea during the shocks, and, on those parts of the coast where the movement was most violent, all kinds of fish were taken in abundance, and with unusual facility. Some rare species, as that called Cicirelli, which usually lie buried in the sand, were taken on the surface of the waters in great quantity. The sea is said to have boiled up near Messina and to have been agitated as if by a copious discharge of vapours from its bottom.

Shore near Scilla inundated.—The prince of Scilla had persuaded a great part of his vassals to betake themselves to their fishing-boats for safety, and he himself had gone on board. On the night of February 5, when some of the people were sleeping in the boats, and others on a level plain slightly elevated above the sea, the earth rocked, and suddenly a great mass was torn from the contiguous Mount Jaci, and thrown down with a dreadful crash upon the plain. Immediately afterwards, the sea, rising more than 20 feet above the level of this low tract, rolled foaming over it, and swept away the multitude. It then retreated, but soon rushed back again with greater violence, bringing with it some of the people and animals it had carried away. At the same time every boat was sunk or dashed against the beach, and some of them were swept far inland. The aged prince, with 1,430 of his people, was destroyed.

State of Stromboli and Etna during the shocks.—The inhabitants of Pizzo remarked that, on February 5, 1783, when the first great shock affected Calabria, the volcano of Stromboli, which is in full view of that town, and at the distance of about 50 miles, smoked less, and threw up a less quantity of inflamed matter, than it had done for some years previously. On the other hand, the great crater of Etna is said to have given out a considerable quantity of vapour towards the beginning, and Stromboli towards the close, of the commotions. But as no eruption happened from either of these great vents during the whole earthquake, the sources of the Calabrian convulsions, and of the volcanic fires of Etna and Stromboli, appear to be very independent of each other; unless, indeed, they have the same mutual relation as Vesuvius and the volcanos of the Phlegræan Fields and Ischia, a violent disturbance in one district serving as a safety valve to the other, and both never being in full activity at once.

Origin and mode of propagation of earthquake-waves.—We have already hinted in Chapter XXIII. that there are good reasons for suspecting that the subterranean causes of the earthquake and volcano are the same. In what manner portions of the solid crust of the earth may be melted from time to time so as to form reservoirs of fused matter at various depths, will be considered in Chapter XXXII. Assuming for the present the existence of such reservoirs of liquid lava in the interior, it is not difficult to understand how steam may be generated whenever rain-water or the waters of the sea, percolating through rocks, gain access to such lava, and how, when steam is generated, the incumbent crust of the earth may be rent and dislocated.

During such movements fissures may be formed and injected with gaseous or fluid matter, which may sometimes fail to reach the surface, while at other times it may be expelled through volcanic vents, stufas and hot springs. When the strain on the rocks has caused them to split, or the roofs of pre-existing fissures or caverns have been made to fall in, vibratory jars will be produced and propagated in all directions, like waves of sound through the crust of the earth with varying velocity, according to the violence of the

original shock, and the density or elasticity of the substances through which they pass. They will travel, for example, faster through granite than through limestone, and more rapidly through the latter than through wet clay, but the rate will be uniform through the same homogeneous medium. To the inhabitants of a shaken district the wave or vibration appears to radiate horizontally, outwards from the spot on the surface where it is first felt; but the force does not really operate in a horizontal direction like a wave caused by a pebble on the surface of a pond, for at every point except that immediately above the focus of the shock it comes up obliquely from below, causing the ground to move forwards

Fig. 126.

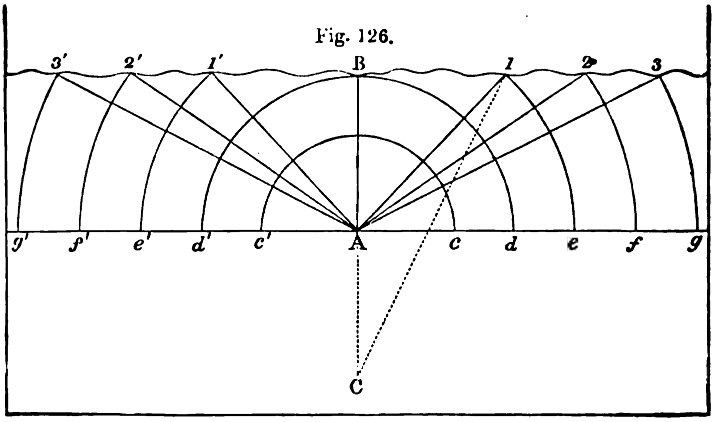


Diagram showing the mode in which an earthquake-wave is transmitted from a subterranean focus of disturbance such as A.

A. Focus of earthquake.

B. Seismic vertical, or point where the shock first reaches the surface.

C. Supposed focus of greater depth. Here the line C, 1, representing the angle of emergence, is steeper than the line A, 1. (See p. 139.)

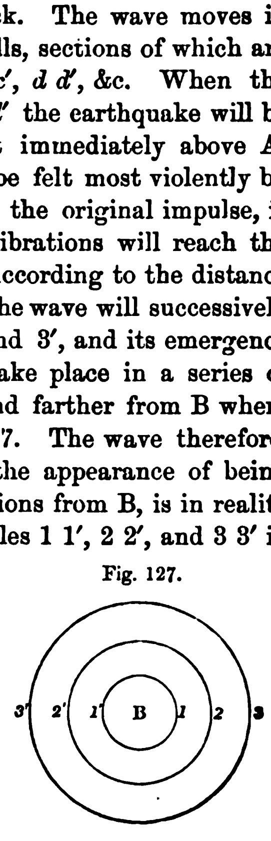
c, *c'*, *d*, *d'*, etc. Section of spherical shells showing the manner in which the earthquake-wave is propagated in all directions from the centre of disturbance, A.

1, 1', Coseismic points, or points on the surface reached simultaneously by the earthquake-wave. So also 2, 2'. 3, 3'.

and then backwards in a more or less horizontal direction, so that all objects which do not participate fully in the movements, such as the walls of a building, appear to move in a direction contrary to that of the ground, and fall by their own weight or inertia. The mode in which the wave is transmitted will be best understood by the accompanying diagram, fig. 126. Suppose the subterranean centre of disturbance to be several miles below the surface or at A, the

crust of the earth being homogeneous, the shock will proceed in all directions as a wave of compression displacing the particles of the vibrating medium for a certain space, and then allowing them to recover their original position usually without fracture of the rock. The wave moves in the form of a series of spherical shells, sections of which are represented in the diagram at *c c′*, *d d′*, &c. When the movement extends to the circle *d d′* the earthquake will be first felt at the surface at a point immediately above A. This point B, where the shock will be felt most violently by the inhabitants as being nearest to the original impulse, is called the seismic vertical. The vibrations will reach the points 1 and 1′ some seconds later according to the distance of such points from the focus A. The wave will successively reach the points 2 and 2′, and 3 and 3′, and its emergence at the surface of the country will take place in a series of concentric rings receding farther and farther from B where the shock was first felt, as in fig. 127. The wave therefore, or vibratory jar, although having the appearance of being propagated horizontally in all directions from B, is in reality transmitted direct from A. The circles 1 1′, 2 2′, and 3 3′ in figs. 126 and 127 are called coseismal circles, because all points in their circumference are simultaneously shaken. The reader will observe that all these spherical shells *c c′*, *d d′*, and the points of emergence, 1, 2, 3, &c., relate to the continuous transmission through the earth of a single shock, and not to a series of separate waves following each other. Mr. Robert Mallet and the late Mr. Hopkins have endeavoured to devise instruments and methods of observation, by which the rate of transit of the earthquake-wave, and the depth of the focus of disturbance, might be measured.

Fig. 127.



B. Seismic vertical.
1, 2, 3. Coseismic points with 1′, 2′, 3′, respectively.

Mr. Mallet* has the merit of having been the first to make a practical application of the rules deduced from mechanical

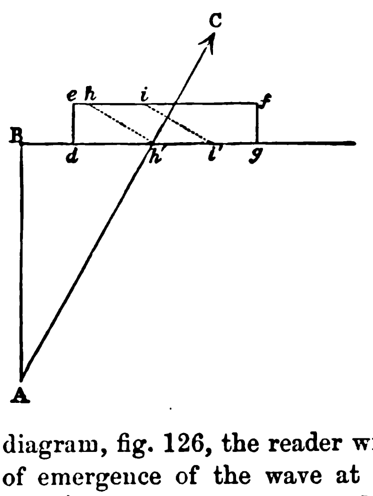
* Great Neapolitan Earthquake of 1857; in two vols. London, 1862.

principles bearing on this subject. With this object he visited part of the Neapolitan territory, shortly after the great earthquake of December, 1857. The region most violently shaken at that period was about 40 miles east of Salerno, in latitude 40° 30′ N., wholly to the north of the district convulsed in 1783. Although many towns were then laid in ruins, and there was much loss of life, the destruction was by no means so great as that of 1783, and the changes wrought in the river-courses were not on so grand a scale.

To obtain the seismic vertical Mr. Mallet observed the direction in which chimneys, urns, and statues had been thrown down from the tops of high buildings. Such bodies in consequence of their inertia usually fall backwards in the direction from which the shock comes, but sometimes they are thrown forwards. In either case they indicate the direction of the shocks, and two or more such lines of direction prolonged to their point of intersection give the seismic vertical. That point being found, the next step is to ascertain the angle at which the wave emerged at different points at the surface.

Suppose a rectangular building *d, e, f, g* (fig. 128), to stand with its principal walls in the direction of the shock, and the earthquake-wave to emerge in the direction A, C. The shock will tend to produce fissures *h h′*, *i*, *i′*, at right angles to its own path. The inclination of A, C, to the horizon, or the angle of emergence, being thus known by reference to these fissures, we obtain the position of the focus A, by imagining the line C, *h′*, to be prolonged till it meets the vertical line B, A.

Fig. 128.



By referring to the former diagram, fig. 126, the reader will at once see that the angle of emergence of the wave at any given distance from the seismic vertical, B, will depend upon the depth of the focus;

in other words, it will be always steeper as the depth increases, as the line C, 1, for example, is more steeply inclined than A, 1.

By aid of a dynamical formula which we need not cite here, Mr. Mallet came to the conclusion that the depth of the original shock in 1857 did not exceed 7 or 8 miles, and although this can only be a rough approximation to the truth it is of considerable interest, and the repetition of such investigations may hereafter lead to more reliable results, especially when observations in regard to the time, direction, and intensity of the shocks shall have been made with scientific care at the moment of the convulsion. Such observations require the aid of delicate instruments, and the problem is exceedingly complicated, far more so than the reader may have inferred from the simple illustration above given. For in the first place the shock which produces the vibration or earthquake-wave does not give rise to a single movement, as above supposed, but to two movements, one longitudinal and the other transverse; the second of which at the outset follows the principal one almost instantaneously, and is at right angles to it; but, as this latter vibration travels somewhat slower than the former, it reaches the surface, if the distance be considerable, after a distinct interval of time, and often does more mischief to buildings than the first. It will also be seen by the elaborate report of Mr. Hopkins* that the earthquake-wave, when it passes through rocks differing in density and elasticity, changes in some degree not only its velocity but its direction, being both refracted and reflected in a manner analogous to that of light when it passes from one medium to another of a different density. When the shock traverses the earth's crust through a thickness of several miles, it will encounter a great variety of rocks as well as rents and faults by which the course of the vibratory movements will be more or less interfered with. The fracture also of buildings is considerably modified by the nature of their component materials, and of the coherence of the mortar by which stones or bricks are cemented together.

* Geological Theories of Elevation and Earthquakes, Brit. Assoc. 1847, p. 33.

We must make due allowance therefore for the uncertainty of the data at Mr. R. Mallet's disposal when he attempted to compute the depth beneath the surface at which the shock of 1857 originated, and it is still more difficult for us to form a probable conjecture as to the distance from the surface of the point from which the subterranean movements of 1783 may have proceeded. It is a matter, however, of general interest that Mr. Mallet deduces from all the facts at present known to him respecting the movements of earthquakes, that the subterranean points where the shocks originate are never very deep, perhaps never exceeding thirty geographical miles; a very important conclusion should it hereafter be confirmed by observation and theory.

Number of persons who perished during the earthquake of 1783.—The number of persons who perished during the earthquake in the two Calabrias and Sicily, is estimated by Hamilton at about 40,000; and about 20,000 more died by epidemics, which were caused by insufficient nourishment, exposure to the atmosphere, and malaria, arising from the new stagnant lakes and pools.

By far the greater number were buried under the ruins of their houses; but many were burnt to death in the conflagrations which almost invariably followed the shocks. These fires raged the more violently in some cities, such as Oppido, from the immense magazines of oil which were consumed.

Many persons were engulphed in deep fissures, especially the peasants when flying across the open country, and their skeletons may perhaps be buried at various depths in the earth to this day.

When Dolomieu visited Messina after the shock of February 5, he describes the city as still presenting, at least at a distance, an imperfect image of its ancient splendour. Every house was injured, but the walls were standing: the whole population had taken refuge in wooden huts in the neighbourhood, and all was solitude and silence in the streets: it seemed as if the city had been desolated by the plague. 'But when I passed over to Calabria, and first beheld Polistena, the scene of horror almost deprived me of my faculties; my mind was filled with mingled compassion and terror;

nothing had escaped; all was levelled with the dust; not a single house or piece of wall remained; on all sides were heaps of stone so destitute of form that they gave no conception of there ever having been a town on the spot. The stench of the dead bodies still rose from the ruins. I conversed with many persons who had been buried for three, four, or even for five days; I questioned them respecting their sensations in so dreadful a situation, and they agreed that, of all the physical evils they endured, thirst was the most intolerable; and that their mental agony was increased by the idea that they were abandoned by their friends, who might have rendered them assistance.'*

It is supposed that about a fourth part of the inhabitants of Polistena, and of some other towns, were buried alive, and might have been saved had there been no want of hands; but in so general a calamity, where each was occupied with his own misfortunes or those of his family, aid could rarely be obtained. Neither tears, nor supplications, nor promises of high rewards were listened to. Many acts of self-devotion, prompted by parental and conjugal tenderness, or by friendship, or the gratitude of faithful servants, are recorded; but individual exertions were, for the most part, ineffectual. It frequently happened, that persons in search of those most dear to them could hear their moans—could recognise their voices—were certain of the exact spot where they lay buried beneath their feet, yet could afford them no succour. The piled mass resisted all their strength, and rendered their efforts of no avail.

At Terranuova, four Augustin monks, who had taken refuge in a vaulted sacristy, the arch of which continued to support an immense pile of ruins, made their cries heard for the space of four days. One only of the brethren of the whole convent was saved, and 'of what avail was his strength to remove the enormous weight of rubbish which had overwhelmed his companions?' He heard their voices die away gradually; and when afterwards their four corpses were disinterred, they were found clasped in each other's arms. Affecting narratives

* Pinkerton's Voyages and Travels, vol. v. as cited above, p. 117, note.

are preserved of mothers saved after the fifth, sixth, and even seventh day of their interment, when their infants or children had perished with hunger.

It might have been imagined that the sight of sufferings such as these would have been sufficient to awaken sentiments of humanity and pity in the most savage breasts; but while some acts of heroism are related, nothing could exceed the general atrocity of conduct displayed by the Calabrian peasants: they abandoned the farms, and flocked in great numbers into the towns—not to rescue their countrymen from a lingering death, but to plunder. They dashed through the streets, fearless of danger, amid tottering walls and clouds of dust, trampling beneath their feet the bodies of the wounded and half-buried, and often stripping them, while yet living, of their clothes.*

But to enter more fully into these details would be foreign to the purpose of the present work, and several volumes would be required to give the reader a just idea of the sufferings which the inhabitants of many populous districts have undergone during the earthquakes of the last 150 years. A bare mention of the loss of life—as that 50,000 or 100,000 souls perished in one catastrophe—conveys to the reader no idea of the extent of misery inflicted: we must learn, from the narratives of eye-witnesses, the various forms in which death was encountered, the numbers who escaped with loss of limbs or serious bodily injuries, and the multitude who were suddenly reduced to penury and want. It has been often remarked that the dread of earthquakes is strongest in the minds of those who have experienced them most frequently; whereas, in the case of almost every other danger, familiarity with peril renders men intrepid. The reason is obvious—scarcely any part of the mischief apprehended in this instance is imaginary; the first shock is often the most destructive; and, as it may occur in the dead of the night, or if by day, without giving the least warning of its approach, no forethought can guard against it; and when the convulsion has begun, no skill, or courage, or presence of mind, can point

* Dolomieu, Pinkerton's Voyages and Travels, vol. v.

out the path of safety. During the intervals, of uncertain duration, (lasting perhaps for centuries), between the more fatal shocks, slight tremors of the soil are not unfrequent; and as these sometimes precede more violent convulsions, they become a source of anxiety and alarm. The terror arising from this cause alone is of itself no inconsiderable evil.

Although sentiments of pure religion are frequently awakened by these awful visitations, yet we more commonly find that an habitual state of fear, a sense of helplessness, and a belief in the futility of all human exertions, prepare the minds of the vulgar for the influence of a demoralising superstition.

Where earthquakes are frequent, there can never be perfect security of property under the best government; industry cannot be assured of reaping the fruits of its labour; and the most daring acts of outrage may occasionally be perpetrated with impunity, when the arm of the law is paralysed by the general consternation. It is hardly necessary to add, that the progress of civilisation and national wealth must be retarded by convulsions which level cities to the ground, destroy harbours, throw down bridges, render roads impassable, and cause the most cultivated valley-plains to be covered with lakes, or the ruins of adjoining hills.

In regions exposed to the frequent recurrence of severe shocks, experience and scientific knowledge might, no doubt, alleviate the evil.

The Calabrian towns of mediæval date were most of them perched, for the purposes of defence and security, on the tops of isolated hills, where they are said to be rocked by every shock like sailors on the top of a mast.* These sites have usually precipices on several sides, over the edges of which the tottering buildings may readily be precipitated together with some of the ground on which their foundations repose. When towns are placed in the more open country, and constructed on such a plan, and of such materials as are best suited to lessen the danger, the loss of life must be sensibly

* Mallet, Neapolitan Earthquake of 1857, vol. i. p. 30.

diminished. That architects do not despair of successfully contending with the danger, is shown by their frequently advertising their houses in Sicily as earthquake-proof.

I shall endeavour to point out in the sequel, that the general tendency of subterranean movements, when their effects are considered for a sufficient lapse of ages, is eminently beneficial, and that they constitute an essential part of that mechanism by which the integrity of the habitable surface is preserved, and the very existence and perpetuation of dry land secured. Why the working of this same machinery should be attended with so much evil, is a mystery far beyond the reach of our philosophy, and must probably remain so until we are permitted to investigate, not our planet alone and its inhabitants, but other parts of the moral and material universe with which they may be connected. Could our survey embrace other worlds, and the events, not of a few centuries only, but of periods as indefinite as those with which geology renders us familiar, some apparent contradictions might be reconciled, and some difficulties would doubtless be cleared up. But even then, as our capacities are finite, while the scheme of the universe may be infinite, both in time and space, it is presumptuous to suppose that all sources of doubt and perplexity would ever be removed. On the contrary, they might, perhaps, go on augmenting in number, although our confidence in the wisdom of the plan of Nature should increase at the same time; for it has been justly said, that the greater the circle of light, the greater the boundary of darkness by which it is surrounded.*

* Sir H. Davy, Consolations in Travel, p. 246

CHAPTER XXX.

EARTHQUAKES—*continued.*

EARTHQUAKE OF JAVA, 1772—TRUNCATION OF A LOFTY CONE—ST. DOMINGO, 1770—LISBON, 1755—GREAT AREA OVER WHICH THE SHOCKS EXTENDED—RETREAT OF THE SEA—PROPOSED EXPLANATIONS—CONCEPTION BAY, 1751—PERMANENT ELEVATION—PERU, 1746—JAVA, 1699—RIVERS OBSTRUCTED BY LANDSLIPS—SUBSIDENCE IN SICILY, 1693—MOLUCCAS, 1693—JAMAICA, 1692—LARGE TRACTS ENGULPHED—PORTION OF PORT ROYAL SUNK—AMOUNT OF CHANGE IN THE LAST 170 YEARS—ELEVATION AND SUBSIDENCE OF LAND IN BAY OF BAIÆ—EVIDENCE OF THE SAME AFFORDED BY THE TEMPLE OF SERAPIS.

IN this chapter, I shall conclude my remarks on the earthquakes of the 18th century, and then pass on to those of earlier date respecting which we have information which may be of interest to the geologist.

Java, 1772.—Truncation of a lofty cone.—In the year 1772, Papandayang, formerly one of the loftiest volcanos in the island of Java, was in eruption. Before all the inhabitants on the declivities of the mountain could save themselves by flight, the ground is said to have given way, and a great part of the volcano to have fallen in and disappeared. It was estimated that an extent of ground of the mountain itself and its immediate environs, 15 miles long and full 6 broad, was by this commotion swallowed up in the bowels of the earth. Forty villages were destroyed, some being engulphed and some covered by the substances thrown out on this occasion, and 2,957 of the inhabitants perished. A proportionate number of cattle were also killed, and most of the plantations of cotton, indigo, and coffee in the adjacent districts were buried under the volcanic matter. This catastrophe appears to have resembled, although on a grander scale, that of the ancient Vesuvius in the year 79. The cone was reduced in height from 9,000 to about 5,000 feet; and

as vapours still escape from the crater on its summit, a new cone may one day rise out of the ruins of the ancient mountain, as the modern Vesuvius has risen from the remains of Somma.*

Junghuhn, who examined the mountain in 1842, was unable to obtain positive proof that there had been a sinking in of the ground, and concluded that, if any, it must have been near the summit of the cone, or where a new crater was formed. He found that the towns and villages destroyed were far distant from the summit, and buried under a mass of ejected materials; so that they seem to have suffered the fate of Herculaneum and Pompeii, and the lowering of the mountain was probably due for the most part to explosion, rather than to engulphment.

St. Domingo, 1770.—During a tremendous earthquake which destroyed a great part of St. Domingo, innumerable fissures were caused throughout the island, from which mephitic vapours emanated and produced an epidemic. *Hot springs* burst forth in many places where there had been no water before; but after a time they ceased to flow.†

In a previous earthquake, in November 1751, a violent shock destroyed the capital, Port au Prince, and part of the coast, twenty leagues in length, sank down, and has ever since formed a bay of the sea.‡

Hindostan, 1762.—The town of Chittagong, in Bengal, was violently shaken by an earthquake, on April 2, 1762, the earth opening in many places, and throwing up water and mud of a sulphureous smell. At a place called Bardavan, a large river was dried up; and at Bar Charra, near the sea, a tract of ground sank down, and 200 persons, with all their cattle, were lost. It is said, that 60 square miles of the Chittagong coast suddenly and permanently subsided during this earthquake, and that Ces-lung-Toom, one of the Mug mountains, entirely disappeared, and another sank so low, that its summit only remained visible. Four hills are also

* Dr. Horsfield, Batav. Trans. vol. viii. p. 26. Raffles's account (History of Java, vol. i.) is derived from Horsfield.

† Essai sur l'Hist. Nat. de l'Isle de St. Domingue. Paris, 1776.

‡ Hist. de l'Acad. des Sciences. 1752. Paris.

described as having been variously rent asunder, leaving open chasms from 30 to 60 feet in width. Towns which subsided several cubits, were overflowed with water; among others, Deep Gong, which was submerged to the depth of 7 cubits. Two volcanos are said to have opened in the Secta Cunda hills. The shock was also felt at Calcutta.* While the Chittagong coast was sinking, a corresponding rise of the ground took place at the island of Ramree, and at Cheduba. (See Map, fig. 65, Vol. I. p. 587.)†

Earthquake of Lisbon, 1755.—*Extent of the shock.*—In no part of the volcanic region of southern Europe, has so tremendous an earthquake occurred in modern times as that which began on November 1, 1755, at Lisbon. The inhabitants had had no warning of the coming danger, when a sound like that of thunder was heard underground, and immediately afterwards a violent shock threw down the greater part of their city. In the course of about six minutes, 60,000 persons perished. The sea first retired and laid the bar dry; it then rolled in, rising 50 feet or more above its ordinary level. The mountains of Arrabida, Estrella, Julio, Marvan, and Cintra, being some of the largest in Portugal, were impetuously shaken, as it were, from their very foundations; and some of them opened at their summits, which were split and rent in a wonderful manner, huge masses of them being thrown down into the subjacent valleys.‡ Flames are related to have issued from these mountains, which are supposed to have been electric; they are also said to have smoked; but vast clouds of dust may have given rise to this appearance.

Subsidence of the quay.—Among other extraordinary events related to have occurred at Lisbon during the catastrophe, was the subsidence of a new quay, built entirely of marble at an immense expense. A great concourse of people had collected there for safety, as a spot where they might be beyond the reach of falling ruins; but suddenly the quay

* M'Clelland's Report on Min. Resources of India, 1838. Calcutta. For other particulars, see Phil. Trans. vol. liii.

† Journ. Asiat. Soc. Bengal. vol. x. pp. 351, 433.

‡ Hist. and Philos. of Earthquakes, p. 317.

sank down with all the people on it, and not one of the dead bodies ever floated to the surface. A great number of boats and small vessels anchored near it, all full of people, were swallowed up, as in a whirlpool.* No fragments of these wrecks ever rose again to the surface, and the water in the place where the quay had stood is stated, in many accounts, to be unfathomable; but Whitehurst says he ascertained it to be 100 fathoms.†

Circumstantial as are the contemporary narratives, I was informed by Mr. F. Freeman, in 1841, that no part of the Tagus was then more than 30 feet deep at high tide, and an examination of the position of the new quay, and the memorials preserved of the time and manner in which it was built, render the statement of so great a subsidence in 1755 quite unintelligible. Perhaps a deep narrow chasm, such as was before described in Calabria (p. 125), opened and closed again in the bed of the Tagus, after swallowing up some vessels and adjoining buildings. We have already seen that such openings may collapse after the shock suddenly, or in places where the strata are of soft and yielding materials, very gradually. According to the observations made at Lisbon, in 1837, by Mr. Sharpe, the destroying effects of this earthquake were confined to the tertiary strata, and were most violent on the blue clay, on which the lower part of the city is constructed. Not a building, he says, on the secondary limestone or the basalt was injured.‡

The area over which this convulsion extended is very remarkable. It has been computed, says Humboldt,§ that on November 1, 1755, a portion of the earth's surface four times greater than the extent of Europe was simultaneously shaken. The shock was felt in the Alps, and on the coast of Sweden, in small inland lakes on the shores of the Baltic, in Thuringia, in the flat country of northern Germany, and in

* Rev. C. Davy's Letters, vol. ii. Letter ii. p. 12. He was at Lisbon at the time, and ascertained that the boats and vessels said to have been swallowed were missing.

† On the Formation of the Earth p. 55.

‡ Proc. Geol. Soc. No. 60, p. 36 1838.

§ Cosmos, vol. i.

Great Britain. The thermal springs of Töplitz dried up, and again returned, inundating everything with water discoloured by ochre. In the islands of Antigua, Barbadoes, and Martinique in the West Indies, where the tide usually rises little more than 2 feet, it suddenly rose above 20 feet, the water being discoloured and of an inky blackness. The movement was also sensible in the great lakes of Canada. At Algiers and Fez, in the north of Africa, the agitation of the earth was as violent as in Spain and Portugal; and at the distance of 8 leagues from Morocco, a village with the inhabitants, to the number of about 8,000 or 10,000 persons, is said to have been swallowed up; the earth soon afterwards closing over them.

Shocks felt at sea.—The shock was felt at sea, on the deck of a ship to the west of Lisbon, and produced very much the same sensation as on dry land. Off St. Lucar, the captain of the ship Nancy felt his vessel so violently shaken, that he thought she had struck the ground; but, on heaving the lead, found a great depth of water. Captain Clark, off Denia, on the east coast of Spain, in latitude 36° 24′ N., between 9 and 10 in the morning, had his ship shaken and strained as if she had struck upon a rock, so that the seams of the deck opened, and the compass was overturned in the binnacle. Another ship, 40 leagues west of St. Vincent, experienced so violent a concussion, that the men were thrown a foot and a half perpendicularly up from the deck.

Rate at which the movement travelled.—The agitation of lakes, rivers, and springs, in Great Britain, was remarkable. At Loch Lomond, in Scotland, for example, the water, without the least apparent cause, rose against its banks, and then subsided below its usual level. This is explained by supposing that the water does not partake of the sudden shove given to the land, so that it dashes over that side of the basin from which the shock is given. The greatest vertical height of the rise in Loch Lomond was 2 feet 4 inches. It is said that the undulatory movement of this earthquake travelled at the rate of 20 miles a minute, its velocity being calculated by the intervals between the time when the first

shock was felt at Lisbon, and its time of occurrence at several distant places.*

Great wave and retreat of the sea.—A great wave swept over the coast of Spain, and is said to have been 60 feet high at Cadiz. At Tangier, in Africa, it rose and fell 18 times on the coast. At Funchal, in Madeira, it rose full 15 feet perpendicular above high-water mark, although the tide, which ebbs and flows there 7 feet, was then at half ebb. Besides entering the city, and committing great havoc, it overflowed other seaports in the island. At Kinsale, in Ireland, a body of water rushed into the harbour, whirled round several vessels, and poured into the market-place.

It was before stated that the sea first retired at Lisbon; and this retreat of the ocean from the shore, at the commencement of an earthquake, and its subsequent return in a violent wave, is a common occurrence. In order to account for the phenomenon, Michell (see Vol. I. p. 61) imagined a subsidence at the bottom of the sea, from the giving way of the roof of some cavity in consequence of a vacuum produced by the condensation of steam. Such condensation, he observes, might be the first effect of the introduction of a large body of water into fissures and cavities already filled with steam, before there has been sufficient time for the heat of the incandescent lava to turn so large a supply of water into steam, which being soon accomplished causes a greater explosion.

Another proposed explanation is, the sudden rise of the land, which would cause the sea to abandon immediately the ancient line of coast; and if the shore, after being thus heaved up, should fall again to its original level, the ocean would return. This theory, however, will not account for the facts observed during the Lisbon earthquake; for the retreat preceded the wave, not only on the coast of Portugal, but also at the island of Madeira, and several other places. If the upheaving of the coast of Portugal had caused the retreat, the motion of the waters, when propagated to Madeira, would have produced a wave previous to the retreat.

The shock transmitted through the earth from Lisbon,

* Geol. Soc. Proceedings, No. 60, p. 36. 1838.

reached Madeira in 25 minutes, and the sea-wave took 2½ hours to travel the same distance, which agrees well with the time which it required to reach other places according to their distance. We cannot, therefore, explain the great motion of the waters at Madeira by a momentary upward movement of the solid crust of the earth, for in that case the rise of the beach would have occurred at the first period or 25 minutes after the Lisbon shock; besides, it will be seen in the sequel, page 153, that where the sea is deep near the shore, and the beach very steep, as in Madeira, the land-wave cannot cause a retreat of the sea.

The following is another solution of the problem, which has been offered:—Suppose a portion of the bed of the sea to be suddenly upheaved; the first effect will be to raise over the elevated part a body of water, the momentum of which will carry it much above the level it will afterwards assume, causing a draught or receding of the water from the neighbouring coasts, followed immediately by the return of the displaced water, which will also be impelled by its momentum much farther and higher on the coast than its former level.*

Mr. Darwin, when alluding to similar waves on the coast of Chili, states his opinion, that 'the whole phenomenon is due to a common undulation in the water, proceeding from a line or point of disturbance some little way distant. If the waves,' he says, 'sent off from the paddles of a steam-vessel be watched breaking on the sloping shore of a still river, the water will be seen first to retire two or three feet, and then to return in little breakers, precisely analogous to those consequent on an earthquake.' He also adds, that 'the earthquake-wave occurs some time after the shock, the water at first retiring both from the shores of the mainland and of outlying islands, and then returning in mountainous breakers. Their size is modified by the form of the neighbouring coast; for it is ascertained in South America, that places situated at the head of shoaling bays have suffered most, whereas towns like Valparaiso, seated close on the border of a profound

* Quarterly Review, No. lxxxvi. p. 459.

ocean, have never been inundated, though severely shaken by earthquakes.'*

More recently (February, 1846), Mr. Mallet, in his memoir above cited (p. 137), has endeavoured to bring to bear on this difficult subject the more advanced knowledge obtained of late years respecting the true theory of waves. He conceives that when the origin of the shock is beneath the deep ocean, one wave is propagated through the land, and another moving with inferior velocity is formed on the surface of the ocean. This last rolls in upon the land long after the earth-wave has arrived and spent itself. However irreconcilable it may be to our common notions of solid bodies, to imagine them capable of transmitting, with such extreme velocity, motions analogous to tidal waves, it seems nevertheless certain that such undulations are produced, and it is supposed that when the shock passes a given point, each particle of the solid earth describes part of an ellipse in space. The facility with which all the particles of a solid mass can be made to vibrate may be illustrated, says Gay-Lussac, by many familiar examples. If we apply the ear to one end of a long wooden beam, and listen attentively when the other end is struck by a pin's head, we hear the shock distinctly; which shows that every fibre throughout the whole length has been made to vibrate. The rattling of carriages on the pavement shakes the largest edifices; and in the quarries underneath some quarters in Paris, it is found that the movement is communicated through a considerable thickness of rock.†

The great sea-wave originating directly over the centre of disturbance is propagated, as Michell correctly stated, in every direction, like the circle upon a pond when a pebble is dropped into it, the different rates at which it moves depending (as he also suggested) on variations in the depth of the water. This wave of the sea, says Mr. Mallet, is raised by the impulse of the shock immediately below it, which in great earthquakes lifts up the ground 2 or 3 feet vertically. The velocity of the shock, or earth-wave, is greater because

* Darwin's Travels in South America, &c. 1832 to 1836. Voyage of H.M.S. Beagle, vol. iii. p. 377.

† Ann. de Ch. et de Ph. tom. xxii. p. 428.

it 'depends upon a function of the elasticity of the crust of the earth, whereas the velocity of the sea-wave depends upon a function of the depth of the sea.'

'Although the shock in its passage under the deep ocean gives no trace of its progress, it no sooner gets into soundings or shallow water, than it gives rise to another and smaller wave of the sea. It carries, as it were, upon its back, this lesser aqueous undulation; a long narrow ridge of water, which corresponds in form and velocity to itself, being pushed up by the partial elevation of the bottom. It is this small wave, called technically the "forced sea-wave," which communicates the earthquake-shock to ships at sea, as if they had struck upon a rock. It breaks upon a coast at the same moment that the shock reaches it, and sometimes it may cause an apparent slight recession from the shore, followed by its flowing up somewhat higher than the usual tide mark: this will happen where the beach is very sloping, as is usual where the sea is shallow, for then the velocity of the low flat earth-wave is such, that it slips, as it were, from under the undulation in the fluid above. It does this at the moment of reaching the beach, which it elevates by a vertical height equal to its own, and as instantly lets drop again to its former level.'

'While the shock propagated through the solid earth has thus travelled with extra rapidity to the land, the great sea-wave has been following at a slower pace, though advancing at the rate of several miles in a minute. It consists, in the deep ocean, of a long low swell of enormous volume, having an equal slope before and behind, and that so gentle that it might pass under a ship without being noticed. But when it reaches the edge of soundings, its front slope, like that of a tidal wave under similar circumstances, becomes short and steep, while its rear slope is long and gentle. If there be water of some depth close into shore, this great wave may roll in long after the shock, and do little damage: but if the shore be shelving, there will be first a retreat of the water, and then the wave will break upon the beach and roll in far upon the land.'*

* Mallet, Proceed. Roy. Irish Acad. 1846.

The various opinions which have been offered by Michell and later writers, respecting the remote causes of earthquake shocks in the interior of the earth, will more properly be discussed in Chapter XXXIII.

Chili, 1751.—On May 24, 1751, the ancient town of Conception, otherwise called Penco, was totally destroyed by an earthquake, and the sea rolled over it. (See plan of the bay, fig. 110, p. 92.) The ancient port was rendered entirely useless, and the inhabitants built another town about 10 miles from the sea-coast, in order to be beyond the reach of similar inundations. At the same time, a colony recently settled on the sea-shore of Juan Fernandez was almost entirely overwhelmed by a wave which broke upon the shore.

It has been already stated, that in 1835, or 84 years after the destruction of Penco, the same coast was overwhelmed by a similar flood from the sea during an earthquake; and it is also known that 21 years before (or in 1730), a like wave rolled over these fated shores, in which many of the inhabitants perished. A series of similar catastrophes has also been tracked back as far as the year 1590,* beyond which we have no memorials save those of oral tradition. Molina, who has recorded the customs and legends of the aborigines, tells us, that the Araucanian Indians, a tribe inhabiting the country between the Andes and the Pacific, including the part now called Chili, 'had among them a tradition of a great deluge, in which only a few persons were saved, who took refuge upon a high mountain called Thegtheg, "the thundering," which had three points.' Whenever a violent earthquake occurs, these people fly for safety to the mountains, assigning as a reason, that they are fearful, after the shock, that the sea will again return and deluge the world.†

Notwithstanding the tendency of writers in his day to refer all traditionary inundations to one remote period, Molina remarks that this flood of the Araucanians 'was probably very different from that of Noah.' We have, indeed, no means of conjecturing how long this same tribe

* See Father Acosta's work; and Sir Woodbine Parish, Geol. Soc. Proceedings, vol. ii. p. 215.

† Molina, Hist. of Chili, vol. ii.

had flourished in Chili, but we can scarcely doubt, that if its experience reached back even for three or four centuries, several inroads of the ocean must have occurred within that period. But the memory of a succession of physical events, similar in kind, though distinct in time, can never be preserved by a people destitute of written annals. Before two or three generations have passed away all dates are forgotten, and even the events themselves, unless they have given origin to some customs, or religious rites and ceremonies. Oftentimes the incidents of many different earthquakes and floods become blended together in the same narrative; and in such cases the single catastrophe is described in terms so exaggerated, or is so disguised by mythological fictions, as to be utterly valueless to the man of science.

Proofs of elevation of the coast.—During a late survey of Conception Bay, Captains Beechey and Sir E. Belcher discovered that the ancient harbour, which formerly admitted all large merchant vessels which went round Cape Horn, is now occupied by a reef of sandstone, certain points of which project above the sea at low water, the greater part being very shallow. A tract of 1½ mile in length, where, according to the report of the inhabitants, the water was formerly 4 or 5 fathoms deep, is now a shoal; consisting, as our hydrographers found, of hard sandstone, so that it cannot be supposed to have been formed by recent deposits of the river Biobio, an arm of which carries down loose micaceous sand into the same bay.

It is impossible at this distance of time to affirm that the bed of the sea was uplifted at once to the height of 24 feet, during the single earthquake of 1751, because other movements may have occurred subsequently; but it is said, that ever since the shock of 1751, no vessels have been able to approach within 1½ mile of the ancient port of Penco. (See Map, p. 92.) In proof of the former elevation of the coast near Penco, our surveyors found above high-water mark an enormous bed of shells of the same species as those now living in the bay, filled with micaceous sand like that which the Biobio now conveys to the bay. These shells, as well as others, which cover the adjoining hills of mica-schist

to the height of several hundred feet, have been examined by experienced conchologists, and identified with those taken at the same time in a living state from the bay and its neighbourhood.*

Ulloa, therefore, was perfectly correct in his statement that, at various heights above the sea between Talcahuano and Conception, 'mines were found of various sorts of shells used for lime of the very same kinds as those found in the adjoining sea.' Among them he mentions the great mussel called Choros, and two others which he describes. Some of these, he says, are entire, and others broken; they occur at the bottom of the sea, in 4, 6, 10, or 12 fathom water, wherè they adhere to a sea-plant called Cochayuyo. They are taken in dredges, and have no resemblance to those found on the shore or in shallow water; yet beds of them occur at various heights on the hills. 'I was the more pleased with the sight,' he adds, 'as it appeared to me a convincing proof of the universality of the deluge, although I am not ignorant that some have attributed their position to other causes.'† It has, however, been ascertained that the foundation of the Castle of Penco was so low in 1835, or at so inconsiderable an elevation above the highest spring tides, as to discountenance the idea of any permanent upheaval in modern times, on the site of that ancient port; but no exact measurements or levellings appear as yet to have been made to determine this point, which is the more worthy of investigation, because it may throw some light on an opinion often promulgated of late years, that there is a tendency in the Chilian coast, after each upheaval, to sink gradually and return towards its former position.

Peru, 1746.—Peru was visited, on October 28, 1746, by a tremendous earthquake. In the first 24 hours, 200 shocks were experienced. The ocean twice retired and returned impetuously upon the land: Lima was destroyed, and part of the coast near Callao was converted into a bay: 4 other harbours, among which were Cavalla and Guanape, shared

* Captain Belcher showed me these shells, and the collection was examined by Mr. Broderip.

† Ulloa's Voyage to South America, vol. ii. book viii. ch. vi.

the same fate. There were 23 ships and vessels, great and small, in the harbour of Callao, of which 19 were sunk; and the other 4, among which was a frigate called St. Fermin, were carried by the force of the waves to a great distance up the country, and left on dry ground at a considerable height above the sea. The number of inhabitants in this city amounted to 4,000. 200 only escaped, 22 of whom were saved on a small fragment of the fort of Vera Cruz, which remained as the only memorial of the town after this dreadful inundation. Other portions of its site were completely covered with heaps of sand and gravel.

A volcano in Lucanas burst forth the same night, and such quantities of water descended from the cone that the whole country was overflowed; and in the mountain near Pataz, called Conversiones de Caxamarquilla, three other volcanos burst out, and frightful torrents of water swept down their sides.*

There are several records of prior convulsions in Peru, accompanied by similar inroads of the sea, one of which happened 59 years before (in 1687), when the ocean, according to Ulloa, first retired and then returned in a mountainous wave, overwhelming Callao and its environs, with the miserable inhabitants.† This same wave, according to Lionel Wafer, carried ships a league into the country, and drowned man and beast for 50 leagues along the shore.‡ Inundations of still earlier dates are carefully recorded by Ulloa, Wafer, Acosta, and various writers, who describe them as having expended their chief fury some on one part of the coast, some on another.

But all authentic accounts cease when we ascend to the era of the conquest of Peru by the Spaniards. The ancient Peruvians, although far removed from barbarism, were without written annals, and therefore unable to preserve a distinct recollection of a long series of natural events. They had, however, according to Antonio de Herrera, who, in the beginning of the 17th century, investigated their antiquities,

* Ulloa's Voyage to South America, vol. ii. book vii. chap. vii.

† Ibid. vol. ii. p. 82.

‡ Wafer, cited by Sir W. Parish, Geol. Soc. Proceedings, vol. ii. p. 215.

a tradition, 'that many years before the reign of the Incas, at a time when the country was very populous, there happened a great flood; the sea breaking out beyond its bounds, so that the land was covered with water and all the people perished. To this the Guacas, inhabiting the vale of Xausca, and the natives of Chiquito, in the province of Callao, add that some persons remained in the hollows and caves of the highest mountains, who again peopled the land. Others of the mountain people affirm that all perished in the deluge, only 6 persons being saved on a float, from whom descended all the inhabitants of that country.'*

On the mainland near Lima, and on the neighbouring island of San Lorenzo, Mr. Darwin found proofs that the ancient bed of the sea had been raised to the height of more than 80 feet above water within the human epoch, strata having been discovered at that altitude, containing pieces of cotton thread and plaited rush, together with sea-weed and marine shells.† The same author learnt from Mr. Gill, a civil engineer, that he discovered in the interior near Lima, between Casma and Huaraz, the dried-up channel of a large river, sometimes worn through solid rock, which, instead of continually ascending towards its source, has, in one place, a steep downward slope in that direction, for a ridge or line of hills has been uplifted directly across the bed of the stream, which is now arched. By these changes the water has been turned into some other course; and a district, once fertile, and still covered with ruins, and bearing the marks of ancient cultivation, has been converted into a desert.‡

Java, 1699.—On January 5, 1699, a terrible earthquake visited Java, and no less than 208 considerable shocks were reckoned. Many houses in Batavia were overturned, and the flame and noise of a volcanic eruption were seen and heard in that city, which were afterwards found to proceed from Mount Salek, § a volcano 6 days' journey distant. Next morning the Batavian river, which has its rise from that mountain, became very high and muddy, and brought

* Hist. of America, decad. iii. book xi. ch. i.

† Darwin's Journal, p. 451.

‡ Ibid. p. 413.

§ Misspelt 'Sales' in Hooke's Account.

down abundance of bushes and trees, half burnt. The channel of the river being stopped up, the water overflowed the country round the gardens about the town, and some of the streets, so that fishes lay dead in them. All the fish in the river, except the carp, were killed by the mud and turbid water. A great number of drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down by the current; and, 'notwithstanding,' observes one of the writers, 'that a crocodile is amphibious, several of them were found dead among the rest.'*

It is stated that seven hills bounding the river sank down; by which must be meant, as by similar expressions in the description of the Calabrian earthquakes, seven great landslips. These hills, descending some from one side of the valley and some from the other, filled the channel, and the waters then finding their way under the mass, flowed out thick and muddy. The Tangaran river was also dammed up by nine hills, and in its channel were large quantities of drift trees. Seven of its tributaries also are said to have been 'covered up with earth.' A high tract of forest land, between the two great rivers before mentioned, is described as having been changed into an open country, destitute of trees, the surface being spread over with a fine red clay. This part of the account may, perhaps, merely refer to the sliding down of woody tracts into the valleys, as happened to so many extensive vineyards and olive-grounds, in Calabria, in 1783. The close packing of large trees in the Batavian river is represented as very remarkable, and it attests in a striking manner the destruction of soil bordering the valleys which had been caused by floods and landslips.†

Quito, 1698.—In Quito, on the 19th of July, 1698, during an earthquake, a great part of the crater and summit of the volcano Carguairazo fell in, and a stream of water and mud issued from the broken sides of the hill.‡

Sicily, 1693.—Shocks of earthquakes spread over all Sicily in 1693, and on the 11th of January the city of Catania and 49 other places were levelled to the ground, and about

* Hooke's Posthumous Works, p. 437. 1705.

† Phil. Trans. 1700.

‡ Humboldt, Atl. Pit. p. 106.

100,000 people killed. The bottom of the sea, says Vicentino Bonajutus, sank down considerably, in the ports, inclosed bays, and open parts of the coast, and water bubbled up along the shores. Numerous long fissures of various breadths were caused, which threw out sulphurous water; and one of them, in the plain of Catania (the delta of the Simeto), at the distance of 4 miles from the sea, sent forth water as salt as the sea. The stone buildings of a street in the city of Noto, for the length of half a mile, sank into the ground, and remained hanging on one side. In another street, an opening large enough to swallow a man and horse appeared.*

Moluccas, 1693.—The small Isle of Sorea, which consists of one great volcano, was in eruption in the year 1693. Different parts of the cone fell, one after the other, into a deep crater, until almost half the space of the island was converted into a fiery lake. Most of the inhabitants fled to Banda; but great pieces of the mountain continued to fall down, so that the lake of lava became wider; and finally the whole population was compelled to emigrate. It is stated that, in proportion as the burning lake increased in size, the earthquakes were less vehement.†

Jamaica, 1692.—*Subsidence in the harbour.*—In the year 1692, the island of Jamaica was visited by a violent earthquake; the ground swelled and heaved like a rolling sea, and was traversed by numerous cracks, 200 or 300 of which were often seen at a time, opening and then closing rapidly again. Many people were swallowed up in these rents; some the earth caught by the middle, and squeezed to death; the heads of others only appeared above ground; and some were first engulphed, and then cast up again with great quantities of water. Such was the devastation, that even in Port Royal, then the capital, where more houses are said to have been left standing than in the whole island besides, three-quarters of the buildings, together with the ground they stood on, sank down with their inhabitants entirely under water.

The large store-houses on the harbour side subsided, so as

* Phil. Trans. 1693–4. † De la Bêche, Manual of Geol., p. 133, 2nd edition.

to be 24, 36, and 48 feet under water; yet many of them appear to have remained standing, for it is stated that, after the earthquake, the mast-heads of several ships wrecked in the harbour, together with the chimney-tops of houses, were just seen projecting above the waves. A tract of land round the town, about 1,000 acres in extent, sank down in less than one minute, during the first shock, and the sea immediately rolled in. The Swan frigate, which was repairing in the wharf, was driven over the tops of many buildings, and then thrown upon one of the roofs, through which it broke. The breadth of one of the streets is said to have been doubled by the earthquake.

According to Sir H. de la Bêche, the part of Port Royal described as having sunk was built upon newly-formed land, consisting of sand, in which piles had been driven; and the *settlement* of this loose sand, charged with the weight of heavy houses, may, he suggests, have given rise to the subsidences alluded to.*

There have undoubtedly been instances in Calabria and elsewhere of slides of land on which the houses have still remained standing; and it is possible that such may have been the case at Port Royal. The fact at least of submergence is unquestionable, for I was informed by the late Admiral Sir Charles Hamilton that he frequently saw the submerged houses of Port Royal in the year 1780, in that part of the harbour which lies between the town and the usual anchorage of men-of-war. Bryan Edwards also says, in his History of the West Indies, that in 1793 the *ruins* were visible in clear weather from the boats which sailed over them.† Lastly, Lieutenant B. Jeffery, R.N., told me that, being engaged in a survey between the years 1824 and 1835, he repeatedly visited the site in question, where the depth of the water is from 4 to 6 fathoms, and whenever there was but little wind perceived distinct traces of houses. He saw these more clearly when he used the instrument called the 'diver's eye,' which is let down below the ripple of the wave.‡

* De la Bêche, Manual of Geol., p. 133, second edition.

† Vol. i. p. 235, 8vo. ed. 3 vols. 1801.

‡ Letter to the Author, May 1838.

At several thousand places in Jamaica the earth is related to have opened. On the north of the island, several plantations, with their inhabitants, were swallowed up, and a lake appeared in their place, covering above 1,000 acres, which afterwards dried up, leaving nothing but sand and gravel, without the least sign that there had ever been a house or a tree there. Several tenements at Yallows were buried under landslips; and one plantation was removed half a mile from its place, the crops continuing to grow upon it uninjured. Between Spanish Town and Sixteen-mile Walk, the high and perpendicular cliffs bounding the river fell in, stopped the passage of the river and flooded the latter place for 9 days, so that the people 'concluded it had been sunk as Port Royal was.' But the flood at length subsided, for the river had found some new passage at a great distance.

Mountains shattered.—The Blue Mountains and others are declared to have been strangely torn and rent. They appeared shattered and half-naked, no longer affording a fine green prospect, as before, but stripped of their woods and natural verdure. The rivers on these mountains first ceased to flow for about 24 hours, and then brought down into the sea, at Port Royal and other places, several hundred thousand tons of timber, which looked like floating islands on the ocean. The trees were in general barked, most of their branches having been torn off in the descent. It is particularly remarked in this, as in the narratives of so many other earthquakes, that fish were taken in great numbers on the coast during the shocks. The correspondents of Sir Hans Sloane, who collected with care the accounts of eye-witnesses of the catastrophe, refer constantly to *subsidences*, and some supposed the whole of Jamaica to have sunk down.*

Reflections on the amount of change since the close of the seventeenth century.—I have now enumerated some few only of the earthquakes of the last and present centuries, respecting which facts illustrative of geological enquiries are on record. Even if my limits permitted, it would be an unprofitable task to examine all the obscure and ambiguous narratives of

* Phil. Trans. 1694.

similar events of earlier epochs; although, if the places were now examined by geologists well practised in the art of interpreting the monuments of physical changes, many events which have happened within the historical era might doubtless be still determined with precision. It must not be imagined that, in the above sketch of the occurrences of a short period, I have given an account of all, or even the greater part, of the mutations which the earth has undergone by the agency of subterranean movements. Thus, for example, the earthquake of Aleppo, in the present century, and of Syria, in the middle of the 18th, would doubtless have afforded numerous phenomena, of great geological importance, had those catastrophes been described by scientific observers. The shocks in Syria in 1759 were protracted for three months, throughout a space of 10,000 square leagues: an area compared to which that of the Calabrian earthquake in 1783 was insignificant. Accon, Saphat, Balbeck, Damascus, Sidon, Tripoli, and many other places, were almost entirely levelled to the ground. Many thousands of the inhabitants perished in each; and, in the valley of Balbeck alone, 20,000 men are said to have been victims to the convulsion. In the absence of scientific accounts, it would be as irrelevant to our present purpose to enter into the details of such calamities, as to follow the track of an invading army, to enumerate the cities burnt or razed to the ground, and reckon the number of individuals who perished by famine or sword.

If such, then, be the amount of ascertained changes in less than two centuries, notwithstanding the extreme deficiency of our records during that brief period, how important must we presume the physical revolutions to have been in the course of 30 or 40 centuries, during which some countries habitually convulsed by earthquakes have been peopled by civilised nations! Towns engulphed during one earthquake may, by repeated shocks, have sunk to great depths beneath the surface, while the ruins remain as imperishable as the hardest rocks in which they are enclosed. Buildings and cities, submerged, for a time, beneath seas or lakes, and covered with sedimentary deposits, must, in some places, have been re-elevated to considerable heights above the level

of the ocean. The signs of these events have, probably, been rendered visible by subsequent mutations, as by the encroachments of the sea upon the coast, by deep excavations made by torrents and rivers, by the opening of new ravines, and chasms, and other effects of natural agents, so active in districts agitated by subterranean movements.

If it be asked why, if such wonderful monuments exist, so few have hitherto been brought to light, we reply—because they have not been searched for. In order to rescue from oblivion the memorials of former occurrences, the enquirer must know what he may reasonably expect to discover, and under what peculiar local circumstances. He must be acquainted with the action and effect of physical causes, in order to recognise, explain, and describe correctly the phenomena when they present themselves.

The best known of the great volcanic regions, of which the boundaries were sketched in Chapter XXII., is that which includes Southern Europe, Northern Africa, and Central Asia; yet nearly the whole, even of this region, must be laid down, in a geological map, as 'Terra Incognita,' for we are only beginning to know something of one small portion of it, viz. the district round Naples; and even here it is to recent antiquarian and geological research, not to history, that we are principally indebted for the information. I shall now proceed to lay before the reader some of the results of modern investigations in the Bay of Baiæ and the adjoining coast.

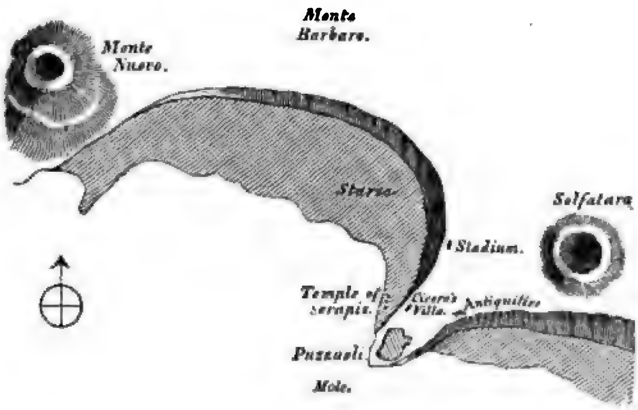
PROOFS OF ELEVATION AND SUBSIDENCE IN THE BAY OF BAIÆ.

Temple of Jupiter Serapis.—This celebrated monument of antiquity, a representation of which is given in the frontispiece* of this work (Vol. I.), affords in itself alone unequivocal evidence that the relative level of land and sea has changed twice at Puzzuoli since the beginning of the Christian

* The view of the Temple given in the frontispiece, Vol. I., has been reduced from part of a beautiful coloured drawing taken in 1836, with the aid of the camera lucida, by Mr. I'Anson, to illustrate a paper by Mr. Babbage on the Temple of Serapis, read March, 1834, and published in the Quart. Journ. of the Geol. Soc. of London, vol. iii. 1847.

era; and each movement, both of elevation and subsidence, has exceeded 20 feet. Before entering on these proofs, I may observe, that a geological examination of the coast of the Bay of Baiæ, both on the north and south of Puzzuoli,

Fig. 129.



Ground plan of the coast of the Bay of Baiæ, in the environs of Puzzuoli.

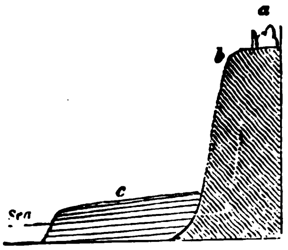
establishes in the most satisfactory manner an elevation, at no remote period, of more than 20 feet, and, at one point, of more than 30 feet; and the evidence of this change would have been complete, even if the temple had, to this day, remained undiscovered.

Coast south of Puzzuoli.—If we coast along the shore from Naples to Puzzuoli, we find on approaching the latter place that the lofty and precipitous cliffs of indurated tuff, resembling that of which Naples is built, retire slightly from the sea; and that a low level tract of fertile land, of a very different aspect, intervenes between the present sea-beach and what was evidently the ancient line of coast.

A portion of the inland cliff may be seen opposite the small island of Nisida, about 2½ miles south-east of Puzzuoli (see Map, fig. 66, Vol. I. p. 600), where, at the height of 32 feet above the level of the sea, Mr. Babbage observed an ancient mark, such as might have been worn by the waves; and, upon further examination, discovered that, along that line, the face of the perpendicular rock, consisting of very hard tuff, was covered with barnacles (*Balanus sulcatus*, Lamk.), and

drilled by boring testacea. Some of the hollows of the lithodomi contained the shells; while others were filled with the valves of a species of Arca.* Nearer to Puzzuoli, the inland cliff is 80 feet high, and as perpendicular as if it were still undermined by the waves. At its base, a new deposit, constituting the fertile tract above alluded to, attains a height of about 20 feet above the sea; and since it is composed of regular sedimentary deposits, containing marine shells, its position proves that, subsequently to its formation, there has been a change of more than 20 feet in the relative level of land and sea.

Fig. 130.



a. Antiquities on hill S.E. of Puzzuoli (see ground plan, fig. 129).
b. Ancient cliff, now inland.
c. Terrace composed of recent submarine deposit.

The sea encroaches on these new incoherent strata; and as the soil is valuable, a wall has been built for its protection; but when I first visited the spot in 1828, the waves had swept away part of this rampart, and exposed to view a regular series of strata of tuff, more or less argillaceous, alternating with beds of pumice and lapilli, and containing great abundance of marine shells, of species now common on this coast, and amongst them *Cardium rusticum*, *Ostrea edulis*, and *Donax trunculus*, Lamk. The strata vary from about a foot to a foot and a half in thickness, and one of them contains abundant remains of works of art, tiles, squares of mosaic pavement of different colours, and small sculptured ornaments, perfectly uninjured. Intermixed with these I collected some teeth of the pig and ox. These fragments of building occur below as well as above strata containing marine shells. Puzzuoli itself stands chiefly on a promontory of the older tufaceous formation, although I detected a small patch of the newer deposit remaining in a garden under the town.

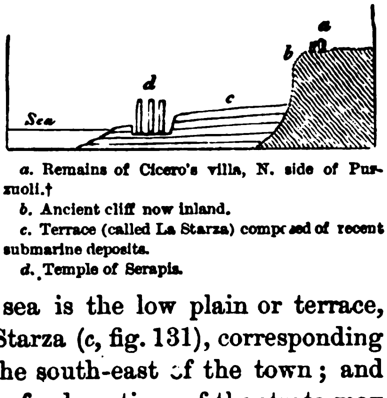
From the town the ruins of a mole, called Caligula's

* Mr. Babbage examined this spot in company with Sir Edmund Head in June 1828, and has shown me numerous specimens of the shells collected there, and in the Temple of Serapis.

Bridge, run out into the sea. (See No. 3, Frontispiece.)* This mole, which is believed to be eighteen centuries old, consists of a number of piers and arches, thirteen of which were standing in 1828, and two others appeared to have been overthrown. Mr. Babbage found, on the sixth pier, perforations of lithodomi four feet above the level of the sea; and, near the termination of the mole on the last pier but one, marks of the same, ten feet above the level of the sea, together with great numbers of balani and flustra. The depth of the sea, at a very small distance from most of the piers, is from 30 to 50 feet.

Coast north of Puzzuoli.—If we then pass to the north of Puzzuoli, and examine the coast between that town and Monte Nuovo, we find a repetition of analogous phenomena. The sloping sides of Monte Barbaro slant down within a short distance of the coast, and terminate in an inland cliff of moderate elevation, to which the geologist perceives at once that the sea must, at some former period, have extended.

Fig. 131.



a. Remains of Cicero's villa, N. side of Puzzuoli.†
b. Ancient cliff now inland.
c. Terrace (called La Starza) composed of recent submarine deposits.
d. Temple of Serapis.

Between this cliff and the sea is the low plain or terrace, before alluded to, called La Starza (*c*, fig. 131), corresponding to that before described on the south-east of the town; and as the sea encroaches rapidly, fresh sections of the strata may readily be obtained, of which the annexed is an example.

Section on the shore north of the Town of Puzzuoli.

	Ft.	In.
1. Vegetable soil	1	0
2. Horizontal beds of pumice and scoriæ, with broken fragments of unrolled bricks, bones of animals, and marine shells	1	6
3. Beds of lapilli, containing abundance of marine shells, principally *Cardium rusticum*, *Donax trunculus*, Lam., *Ostrea edulis*, *Triton cutaceum*, Lam., and *Buccinum serratum*, Brocchi, the beds varying in thickness from one to eighteen inches	10	0
4. Argillaceous tuff, containing bricks and fragments of buildings not rounded by attrition	1	6

* This view is taken from Sir W. Hamilton, Campi Phlegræi, plate 26.

† This spot here indicated on the summit of the cliff is that from which

The thickness of many of these beds varies greatly as we trace them along the shore, and sometimes the whole group rises to a greater height than at the point above described. The surface of the tract which they compose appears to slope gently upwards towards the base of the old cliffs.

Now, if such appearances presented themselves on the coast of England, a geologist might endeavour to seek an explanation in some local change in the set of the tides and currents: but there are scarcely any tides in the Mediterranean; and, to suppose the sea to have sunk generally from twenty to twenty-five feet since the shores of Campania were covered with sumptuous buildings, is an hypothesis obviously untenable. The observations, indeed, made during modern surveys on the moles and cothons (docks) constructed by the ancients in various ports of the Mediterranean, have proved that there has been no sensible variation of level in that sea during the last two thousand years.*

Thus we arrive, without the aid of the celebrated temple, at the conclusion, that the recent marine deposit at Puzzuoli was upraised in modern times above the level of the sea, and that not only this change of position, but the accumulation of the modern strata, was posterior to the destruction of many edifices, of which they contain the embedded relics. If we next examine the evidence afforded by the temple itself, it appears, from the most authentic accounts, that the three pillars now standing erect continued, down to the middle of the last century, almost buried in the new marine strata (c, fig. 131). The upper part of each, protruding several feet above the surface, was concealed by bushes, and had not attracted, until the year 1749, the notice of antiquaries; but, when the soil was removed in 1750, they were seen to form part of the remains of a splendid edifice, the pavement of which was still preserved, and upon it lay a number of columns of African breccia and of granite. The original plan of the building could be traced distinctly: it was of a quadrangular form, 70 feet in diameter, and

Hamilton's view. plate 26, Campi Phlegræi (reduced in Plate VII.), is taken, and on which, he says, Cicero's villa, called the Academia, anciently stood.

* On the authority of the late Admiral Smyth, R.N.

the roof had been supported by 46 noble columns, 24 of granite, and the rest of marble. The large court was surrounded by apartments, supposed to have been used as bathing-rooms; for a thermal spring, still used for medicinal purposes, issues just behind the building, and the water of this spring appears to have been originally conveyed by a marble duct, still extant, into the chambers, and then across the pavement by a groove an inch or two deep, to a conduit made of Roman brickwork, by which it gained the sea.

Many antiquaries have entered into elaborate discussions as to the deity to which this edifice was consecrated. It is admitted that, among other images found in excavating the ruins, there was one of the god Serapis; and at Puzzuoli a marble column was dug up, on which was carved an ancient inscription, of the date 648 after the building of Rome (or B.C. 105), entitled 'Lex parieti faciundo.' This inscription, written in very obscure Latin, sets forth a contract, between the municipality of the town, and a company of builders who undertook to keep in repair certain public edifices, the Temple of Serapis being mentioned amongst the rest, and described as being near or towards the sea, 'ad mare vorsum.' Sir Edmund Head, after studying, in 1828, the topography and antiquities of this district, and the Greek, Roman, and Italian writers on the subject, informed me, that at Alexandria, on the Nile, the chief seat of the worship of Serapis, there was a Serapeum of the same form as this temple at Puzzuoli, and surrounded in like manner by chambers, in which the devotees were accustomed to pass the night, in the hope of receiving during sleep a revelation from the god, as to the nature and cure of their diseases. Hence it was very natural that the priests of Serapis, a pantheistic divinity, who, among other usurpations, had appropriated to himself the attributes of Esculapius, should regard the hot spring as a suitable appendage to the temple, although the original Serapeum of Alexandria could boast no such medicinal waters. Signor Carelli* and others, in objecting to these views, have insisted on the fact, that the worship of Serapis, which we

* Dissertazione sulla Sagra Architettura degli Antichi.

know prevailed at Rome in the days of Catullus (in the first century before Christ), was prohibited by the Roman Senate during the reign of the Emperor Tiberius. But there is little doubt that, during the reigns of that Emperor's successors, the shrines of the Egyptian god were again thronged by zealous votaries; and in no place more so than at Puteoli (now Puzzuoli), one of the principal marts for the produce of Alexandria.

Without entering farther into an enquiry which is not strictly geological, I shall designate this valuable relic of antiquity by its generally received name, and proceed to consider the memorials of physical changes inscribed on the three standing columns in most legible characters by the hand of Nature. (See Frontispiece, Vol. I.) These pillars, which have been carved each out of a single block of marble, are 40 feet 3½ inches in height. A horizontal fissure nearly intersects one of the columns; the other two are entire. They are all slightly out of the perpendicular, inclining somewhat to the south-west, that is, towards the sea.* Their surface is smooth and uninjured to the height of about twelve feet above their pedestals. Above this is a zone, about nine feet in height, where the marble has been pierced by a species of marine perforating bivalve—*Lithodomus*, Cuv.† The holes of these animals are pear-shaped, the external opening being minute, and gradually increasing downwards. At the bottom of the cavities, many shells are still found, notwithstanding the great numbers that have been taken out by visitors; in many the valves of a species of arca, an animal which conceals itself in small hollows, occur. The perforations are so considerable in depth and size, that they manifest a long-continued abode of the lithodomi in the columns; for, as the inhabitant grows older and increases in size, it bores a larger cavity, to correspond with the increased magnitude of its shell. We must, consequently, infer a long-continued im-

* This appears from the measurement of Captain Basil Hall, R.N., Proceedings of Geol. Soc., No. 38, p. 114; see also Patchwork, by the same author, vol. iii. p. 158. The fact of the three standing columns having been each formed out of a single stone was first pointed out to me by Mr. James Hall, and is important, as helping to explain why they were not shaken down.

† *Modiola lithophaga*, Lam. *Mytilus lithophagus*, Linn.

mersion of the pillars in sea-water, at a time when the lowest part was covered up and protected by marine, fresh-water, and volcanic strata, afterwards to be described, and by the rubbish of buildings; the highest part, at the same time, projecting above the waters, and being consequently weathered, but not materially injured. (See fig. 132, p. 172.)

On the pavement of the temple lie some columns of marble, which are also perforated in certain parts; one, for example, to the length of 8 feet, while, for the length of 4 feet, it is uninjured. Several of these broken columns are eaten into, not only on the exterior, but on the cross fracture, and, on some of them, other marine animals (serpulæ, &c.) have fixed themselves.* All the granite pillars are untouched by lithodomi. The platform of the temple, which is not perfectly even, was, when I visited it in 1828, about one foot below high-water mark (for there are small tides in the Bay of Naples); and the sea, which was only 100 feet distant, soaked through the intervening soil. The upper part of the perforations, therefore, was at least 23 feet above high-water mark; and it is clear that the columns must have continued for a long time in an erect position, immersed in salt water, and then the submerged portion must have been upraised to the height of about 23 feet above the level of the sea.

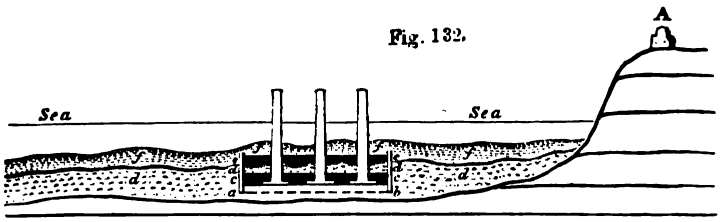
By excavations carried on in 1828, below the marble pavement on which the columns stand, another costly pavement of mosaic was found, at the depth of about 5 feet below the upper one (*a*, *b*, fig. 132). The existence of these two pavements, at different levels, clearly implies some subsidence previous to the building of the more modern temple which had rendered it necessary to construct the new floor at a higher level.

We have already seen (p. 169) that a temple of Serapis existed long before the Christian era. The change of level just mentioned must have taken place some time before the end of the second century, for inscriptions have been found in the temple, from which we learn that Septimius Severus

* *Serpula contortuplicata*, Linn., and *Vermilia triquetra*, Lam. These species, as well as the *Lithodomus*, are now inhabitants of the neighbouring sea.

adorned its walls with precious marbles between the years 194 and 211 of our era, and the Emperor Alexander Severus displayed the like munificence between the years 222 and 235.* From that era there is an entire dearth of historical information for a period of more than twelve centuries, except the significant fact that Alaric and his Goths sacked Puzzuoli in 410, and that Genseric did the like in 445, A.D. Yet we have fortunately a series of natural archives self-registered during the dark ages, by which many events which occurred in and about the temple are revealed to us. These natural records consist partly of deposits, which envelop the pillars below the zone of lithodomous perforations, and partly of those which surround the outer walls of the temple. Mr. Babbage, after a minute examination of these, has shown (see p. 164, note) that incrustations on the walls of the

Fig. 132.



Temple of Serapis at its period of greatest depression.

a b. Ancient mosaic pavement.
c c. Dark marine incrustation.
d d. First filling up, shower of ashes.
e e. Freshwater calcareous deposit.
f f. Second filling up.
A. Stadium.

exterior chambers and on the floor of the building demonstrate that the pavement did not sink down suddenly, but was depressed by a gradual movement. The sea first entered the court or atrium, and mingled its waters partially with those of the hot spring. From this brackish medium a dark calcareous precipitate (*c c*, fig. 132) was thrown down, which became, in the course of time, more than two feet thick, including some serpulæ in it. The presence of these annelids teaches us that the water was salt or brackish. After this period the temple was filled up with an irregular mass of volcanic tuff (*d d*, fig. 132), probably derived from an eruption of the neighbouring crater of the Solfatara, to the

* Brieslak, Voy. dans la Campanie, tom. ii. p. 167.

height of from 5 to 9 feet above the pavement. Over this again a purely freshwater deposit of carbonate of lime (*e e*, fig. 132) accumulated with an *uneven* bottom, since it necessarily accommodated itself to the irregular outline of the upper surface of the volcanic shower before thrown down. The top of the same deposit (a freshwater limestone) was perfectly even and flat, bespeaking an ancient water level. It is suggested by Mr. Babbage that this freshwater lake may have been caused by the fall of ashes which choked up the channel previously communicating with the sea, so that the hot spring threw down calcareous matter in the atrium without any marine intermixture. To the freshwater limestone succeeded another irregular mass of volcanic ashes and rubbish (*f f*, fig. 132), some of it perhaps washed in by the waves of the sea during a storm, its surface rising to 10 or 11 feet above the pavement. And thus we arrive at the period of greatest depression expressed in the accompanying diagram, when the lower half of the pillars was enveloped in the deposits above enumerated, and the uppermost 20 feet were exposed in the atmosphere, the remaining or middle portion, about 9 feet long, being for years immersed in salt water and drilled by perforating bivalves. After this period other strata, consisting of showers of volcanic ashes and materials washed in during storms, covered up the pillars to the height in some places of 35 feet above the pavement. The exact time when these enveloping masses were heaped up, and how much of them was formed during submergence, and how much after the re-elevation of the temple, cannot be made out with certainty.

The period of deep submergence was certainly antecedent to the close of the 15th century. Professor James Forbes* has reminded us of a passage in an old Italian writer, Loffredo, who says that in 1530, or 50 years before he wrote, which was in 1580, the sea washed the base of the hills which rise from the flat land called La Starza, as represented in fig. 132; so that, to quote his words, 'a person might then have fished from the site of those ruins which are now called the stadium' (A, fig. 132).

* Ed. Journ. of Science, New Series, No. II. p. 281.

But we know from other evidence that the upward movement had begun before 1530, for the Canonico Andrea di Jorio cites two authentic documents in illustration of this point. The first, dated Oct. 1503, is a deed written in Italian, by which Ferdinand and Isabella grant to the University of Puzzuoli a portion of land, 'where the sea is drying up' (che va seccando el mare); the second, a document in Latin, dated May 23, 1511, or nearly 8 years after, by which Ferdinand grants to the city a certain territory around Puzzuoli, where the ground *is dried up* (desiccatum).*

The principal elevation, however, of the low tract unquestionably took place at the time of the great eruption of Monte Nuovo in 1538. That event and the earthquakes which preceded it have been already described (Vol. I. p. 610); and we have seen that two of the eye-witnesses of the convulsion, Falconi and Giacomo di Toledo, agree in declaring that the sea abandoned a considerable tract of the shore, so that fish were taken by the inhabitants; and, among other things, Falconi mentions that he saw two springs *in the newly discovered ruins.*

The flat land, when first upraised, must have been more extensive than now, for the sea encroaches somewhat rapidly, both to the north and south-east of Puzzuoli. The coast had, when I examined it in 1828, given way more than a foot in a twelvemonth; and I was assured, by fishermen in the bay, that it has lost ground near Puzzuoli, to the extent of 30 feet, within their memory.

It is, moreover, very probable that the land rose to a greater height at first, before it ceased to move upwards, than the level at which it was observed to stand when the temple was re-discovered in 1749, for we learn from a memoir of Niccolini, published in 1838, that since the beginning of the 19th century, the temple of Serapis has subsided more than 2 feet. That learned architect visited the ruins frequently, for the sake of making drawings, in the beginning of the year 1807, and was in the habit of remaining there throughout the day, yet never saw the pavement overflowed by the

* Sul Tempio di Serap. ch. viii.

sea, except occasionally when the south wind blew violently. On his return, 16 years after, to superintend some excavations ordered by the King of Naples, he found the pavement covered by sea-water twice every day at high tide, so that he was obliged to place there a line of stones to stand upon. This induced him to make a series of observations from Oct. 1822 to July 1838, by which means he ascertained that the ground had been and was sinking, at the average rate of about 7 millimetres a year, or about 1 inch in 4 years; so that, in 1838, fish were caught every day on that part of the pavement where, in 1807, there was never a drop of water in calm weather.*

Mr. Smith, of Jordan Hill, examined the temple in 1847, and came to the conclusion from a comparison of various data that the rate of subsidence at that period was one inch annually.† Signor Scacchi, in 1852, after an examination undertaken by him at my request, inferred that the downward movement had ceased for several years, or had at least become almost inappreciable. I myself made several observations in 1857 and 1858, and came to the conclusion that there was a depth of about 2 feet of water on the pavement near the bronze ring on calm days at high tide when the Bay of Baiæ was not raised above its ordinary level by the wind. Although it would require a long series of measurements to obtain the exact average height of the tide in the bay, I cannot doubt that the relative level of the pavement and the sea has altered very sensibly since Niccolini first frequented the place.

From what was said before (p. 167), we saw that the marine shells in the strata forming the plain called La Starza, considered separately, establish the fact of an upheaval of the ground to the height of 23 feet and upwards. The temple proves much more, because it could not have been built originally under water, and must therefore first have sunk down 20 feet at least below the waves, to be afterwards restored to its original position. Yet if such was the order of events, we ought to meet with other independent

* Tavola Metrica Chronologica, &c. Napoli, 1838.

† Quart. Journ. Geol. Soc. vol. iii. p. 237.

signs of a like subsidence round the margin of a bay once so studded with buildings as the Bay of Baiæ. Accordingly, memorials of such submergence are not wanting. About a mile NW. of the temple of Serapis, and about 500 feet from the shore, are the ruins of a temple of Neptune and others of a temple of the Nymphs, now under water. The columns of the former edifice stand erect in five feet water, their upper portions just rising to the surface of the sea. The pedestals are doubtless buried in the sand or mud; so that, if this part of the bottom of the bay should hereafter be elevated, the exhumation of these temples might take place after the manner of that of Serapis. Both these buildings probably participated in the movement which raised the Starza; but either they were deeper under water than the temple of Serapis, or they were not raised up again to so great a height. There are also two Roman roads under water in the bay, one reaching from Puzzuoli to the Lucrine Lake, which may still be seen, and the other near the castle of Baiæ (No. 8, Frontispiece). The ancient mole, too, of Puzzuoli (No. 4, ibid.), before alluded to, has the water up to a considerable height of the arches; whereas Brieslak justly observes, it is next to certain that the piers must formerly have reached the surface before the springing of the arches;* so that, although the phenomena before described prove that this mole has been uplifted 10 feet above the level at which it once stood, it is still evident that it has not yet been restored to its original position.

A modern writer also reminds us, that these effects are not so local as some would have us to believe; for on the opposite side of the Bay of Naples, on the Sorrentine coast, which, as well as Puzzuoli, is subject to earthquakes, a road, with fragments of Roman buildings, is covered to some depth by the sea. In the island of Capri, also, which is situated some way out at sea, in the opening of the Bay of Naples, one of the palaces of Tiberius is now covered with water.†

* Voy. dans la Campanie, tome ii. p. 162.

† Mr. Forbes, Physical Notices of the Bay of Naples. Ed. Journ. of Sci., No. II., New Series, p. 280. October 1829. When I visited Puzzuoli, and arrived at the above conclusions, I knew nothing of Mr. Forbes's observations, which I first saw on my return to England the year following.

That buildings should have been submerged, and afterwards upheaved, without being entirely reduced to a heap of ruins, will appear no anomaly, when we recollect that, in the year 1819, when the delta of the Indus sank down, the houses within the fort of Sindree subsided beneath the waves without being overthrown (p. 102). In like manner, in the year 1692, the buildings around the harbour of Port Royal, in Jamaica, descended suddenly to the depth of between 30 and 50 feet under the sea without falling (p. 160). Even on small portions of land transported to a distance of a mile down a declivity, tenements, like those near Mileto, in Calabria, were carried entire. At Valparaiso buildings were left standing in 1822, when their foundations, together with a long tract of the Chilian coast, were permanently upraised to the height of several feet (p. 94). It is still more easy to conceive that an edifice may escape falling during the upheaval or subsidence of land, if the walls are supported on the exterior and interior with a deposit like that which surrounded and filled to the height of 10 or 11 feet the temple of Serapis all the time it was sinking, and which enveloped it to more than twice that height when it was rising again to its original level.

We can scarcely avoid the conclusion, as Mr. Babbage has hinted, 'that the action of heat is in some way or other the cause of the phenomenon of the change of level of the temple. Its own hot spring, its immediate contiguity to the Solfatara, its nearness to the Monte Nuovo, the hot spring at the baths of Nero (No. 6, Frontispiece), on the opposite side of the Bay of Baiæ; the boiling springs and ancient volcanos of Ischia on one side and Vesuvius on the other, are the most prominent of a multitude of facts which point to that conclusion.'* And when we reflect on the dates of the principal oscillations of level, and the volcanic history of the country before described (Chapter XXIV.), we seem to discover a connection between each era of upheaval and a local development of volcanic heat, and again between each era of depression and the local quiescence or dormant condition of the subterranean igneous causes. Thus, for example, before

* Quart. Journ. Geol. Soc. 1847, vol. iii. p. 208.

the Christian era, when so many vents were in frequent eruption in Ischia, and when Avernus and other points in the Phlegræan Fields were celebrated for their volcanic aspect and character, the ground on which the temple stood was several feet above water. Vesuvius was then regarded as a spent volcano; but when, after the Christian era, the fires of that mountain were rekindled, scarcely a single outburst was ever witnessed in Ischia, or around the Bay of Baiæ. Then the temple was sinking. Vesuvius, at a subsequent period, became nearly dormant for five centuries preceding the great outbreak of 1631 (see Vol. I. p. 619), and in that interval the Solfatara was in eruption A.D. 1198, Ischia in 1302, and Monte Nuovo was formed in 1538. Then the foundations on which the temple stood were rising again. Lastly, Vesuvius once more became a most active vent, and has been so ever since, and during the same lapse of time the area of the temple, so far as we know anything of its history, has been subsiding.

These phenomena would agree well with the hypothesis, that when the subterranean heat is on the increase, and when lava is forming without obtaining an easy vent, like that afforded by a great habitual chimney, such as Vesuvius, the incumbent surface is uplifted; but when the heated rocks below are cooling and contracting, and sheets of subterranean lava are slowly consolidating and diminishing in volume, then the incumbent land subsides.

Signor Niccolini, when he ascertained in 1838 that the relative levels of the floor of the temple and of the sea were slowly changing from year to year, embraced the opinion that it was the sea which was rising. But Signor Capocci successfully controverted this view, appealing to many appearances which attest the local character of the movements of the adjoining country, besides the historical fact that in 1538, when the sea retired permanently 200 yards from the ancient shore at Puzzuoli, there was no simultaneous retreat of the waters from Naples, Castelamare, and Ischia.*

Permanence of the ocean's level.—In concluding this subject, I may observe, that the interminable controversies to which

* Nuovo Ricerche sul Temp. di Serap.

the phenomena of the Bay of Baiæ gave rise, have sprung from an extreme reluctance to admit that the land, rather than the sea, is subject alternately to rise and fall. Had it been assumed, as most probable, that the level of the ocean was invariable, on the ground that no fluctuations have as yet been clearly established, and that, on the other hand, the continents are inconstant in their level, as has been demonstrated by the most unequivocal proofs again and again, from the time of Strabo to our own times, the appearances of the temple at Puzzuoli could never have been regarded as enigmatical. Even if contemporary accounts had not distinctly attested the upraising of the coast, this explanation should have been proposed in the first instance as the most natural, instead of being now adopted unwillingly when all others have failed.

To the strong prejudices still existing in regard to the mobility of the land, we may attribute the rarity of such discoveries as have been recently brought to light in New Zealand, the Bay of Baiæ, and the Bay of Conception. A false theory, it is well known, may render us blind to facts, which are opposed to our prepossessions, or may conceal from us their true import when we behold them. But it is time that the geologist should, in some degree, overcome those first and natural impressions which induced the poets of old to select the rock as the emblem of firmness—the sea as the image of inconstancy. Our modern poet, in a more philosophical spirit, saw in the sea 'the image of eternity,' and has finely contrasted the fleeting existence of the successive empires which have flourished and fallen on the borders of the ocean with its own unchanged stability.

——— Their decay
Has dried up realms to deserts:—not so thou,
Unchangeable, save to thy wild waves' play:
Time writes no wrinkle on thine azure brow;
Such as creation's dawn beheld, thou rollest now.

CHILDE HAROLD, Canto iv.

CHAPTER XXXI.

ELEVATION AND SUBSIDENCE OF LAND WITHOUT EARTHQUAKES.

CHANGES IN THE RELATIVE LEVEL OF LAND AND SEA IN REGIONS NOT VOLCANIC—OPINION OF CELSIUS THAT THE WATERS OF THE BALTIC SEA AND NORTHERN OCEAN WERE SINKING—OBJECTIONS RAISED TO HIS OPINION—PROOFS OF THE STABILITY OF THE SEA LEVEL IN THE BALTIC—PLAYFAIR'S HYPOTHESIS THAT THE LAND WAS RISING IN SWEDEN—OPINION OF VON BUCH—MARKS CUT ON THE ROCKS—SURVEY OF THESE IN 1820—SIGNS OF OSCILLATIONS IN LEVEL—FISHING HUT BURIED UNDER MARINE STRATA—FACILITY OF APPRECIATING SLIGHT ALTERATIONS OF LEVEL ON THE INNER AND OUTER COAST OF SWEDEN—SUPPOSED MOVEMENT IN OPPOSITE DIRECTIONS IN PROCEEDING FROM THE NORTH CAPE SOUTHWARDS TO SCANIA—CHANGE OF LEVEL ON THE WEST COAST NEAR GOTHENBURG—GEOLOGICAL PROOFS OF THE GREAT OSCILLATION OF LEVEL SINCE THE GLACIAL PERIOD AT UDDEVALLA—UPRAISED MARINE DEPOSITS OF THE WESTERN COAST OF SWEDEN CONTAINING SHELLS OF THE OCEAN, THOSE ON THE EASTERN COAST SHELLS OF THE BALTIC—WHETHER NORWAY IS NOW RISING—MODERN SUBSIDENCE OF PART OF GREENLAND—PROOFS AFFORDED BY THESE MOVEMENTS OF GREAT SUBTERRANEAN CHANGES.

WE have now considered the phenomena of volcanos and earthquakes according to the division of the subject before proposed (Vol. I. p. 577), and have next to turn our attention to those slow and insensible changes in the relative level of land and sea which take place in countries remote from volcanos, and where no violent earthquakes have occurred within the period of human observation. Early in the last century the Swedish naturalist, Celsius, expressed his opinion that the waters, both of the Baltic and Northern Ocean, were gradually subsiding. From numerous observations, he inferred that the rate of depression was about 40 Swedish inches in a century.* In support of this position, he alleged that there were many rocks both on the shores of the Baltic and the ocean known to have been once sunken reefs, and dangerous to navigators,

* The Swedish measure scarcely differs from ours; the foot being divided into twelve inches, and being less than ours by three-eighths of an inch only.

but which were in his time above water—that the waters of the Gulf of Bothnia had been gradually converted into land, several ancient ports having been changed into inland cities, small islands joined to the continent, and old fishing grounds deserted as being too shallow, or entirely dried up. Celsius also maintained, that the evidence of the change rested not only on modern observations, but on the authority of the ancient geographers, who had stated that Scandinavia was formerly an island. This island, he argued, must in the course of centuries, by the gradual retreat of the sea, have become connected with the continent; an event which he supposed to have happened after the time of Pliny, and before the ninth century of our era.

To this argument it was objected that the ancients were so ignorant of the geography of the most northern parts of Europe, that their authority was entitled to no weight; and that their representation of Scandinavia as an island, might with more propriety be adduced to prove the scantiness of their information, than to confirm so bold an hypothesis. It was also remarked, that if the land which connected Scandinavia with the main continent was laid dry between the time of Pliny and the ninth century, to the extent to which it is known to have stood above the sea at the latter period, the rate of depression of the sea could not have been uniform, as was pretended; for it ought to have fallen to a much greater extent in the longer interval between the 9th and 18th centuries, if the rate of movement had been the same.

Many of the proofs relied on by Celsius and his followers were immediately controverted by several philosophers, who saw clearly that a fall of the sea in any one region could not take place without a general sinking of the waters over the whole globe; they denied that this was the fact, or that the depression was universal, even in the Baltic. In proof of the stability of the level of that sea, they appealed to the position of the island of Saltholm, not far from Copenhagen. This island is so low, that in autumn and winter it is permanently overflowed; and it is only dry in summer, when it serves for pasturing cattle. It appears, from the documents of the year 1280, that Saltholm was then also in the same

state, and exactly on a level with the mean height of the sea, instead of having been about 20 feet under water, as it ought to have been, according to the computation of Celsius. Several towns, also, on the shores of the Baltic, as Lubeck, Wismar, Rostock, Stralsund, and others, after 600 and even 800 years, are as little elevated above the sea as at the era of their foundation, being now close to the water's edge. The lowest part of Dantzic was no higher than the mean level of the sea in the year 1000; and after 8 centuries its relative position remains exactly the same.*

Several of the examples of the gain of land and shallowing of the sea pointed out by Celsius, and afterwards by Linnæus, who embraced the same opinions, were ascribed by others to the deposition of sediment at points where rivers entered; and, undoubtedly, Celsius had not sufficiently distinguished between changes due to these causes and such as would arise if the waters of the ocean itself were diminishing. Many large rivers descending from a mountainous country, at the head of the Gulf of Bothnia, enter the sea charged with sand, mud, and pebbles; and it was said that in these places the low land had advanced rapidly, especially near Torneo. At Piteo also, ½ a mile had been gained in 45 years; at Luleo,† no less than 1 mile in 28 years; facts which might all be admitted consistently with the assumption that the level of the Baltic has remained unchanged, like that of the Adriatic, during a period when the plains of the Po and the Adige have greatly extended their area.

It was also alleged that certain insular rocks, once entirely covered with water, had at length protruded themselves above the waves, and grown, in the course of a century and a half, to be 8 feet high. The following attempt was made to explain away this phenomenon:—In the Baltic, large erratic blocks, as well as sand and smaller stones which lie on shoals, are liable every year to be frozen into the ice, where the sea freezes to the depth of 5 or 6 feet. On the melting of the snow in spring, when the sea rises about ½ a fathom, numerous

* For a full account of the Celsian controversy, we may refer our readers to Von Hoff, Geschichte, &c., vol. i. p. 439.

† Piteo and Luleo are spelt, in many English maps, Pitea and Lulea, but the *a* is not sounded in the Swedish diphthong å.

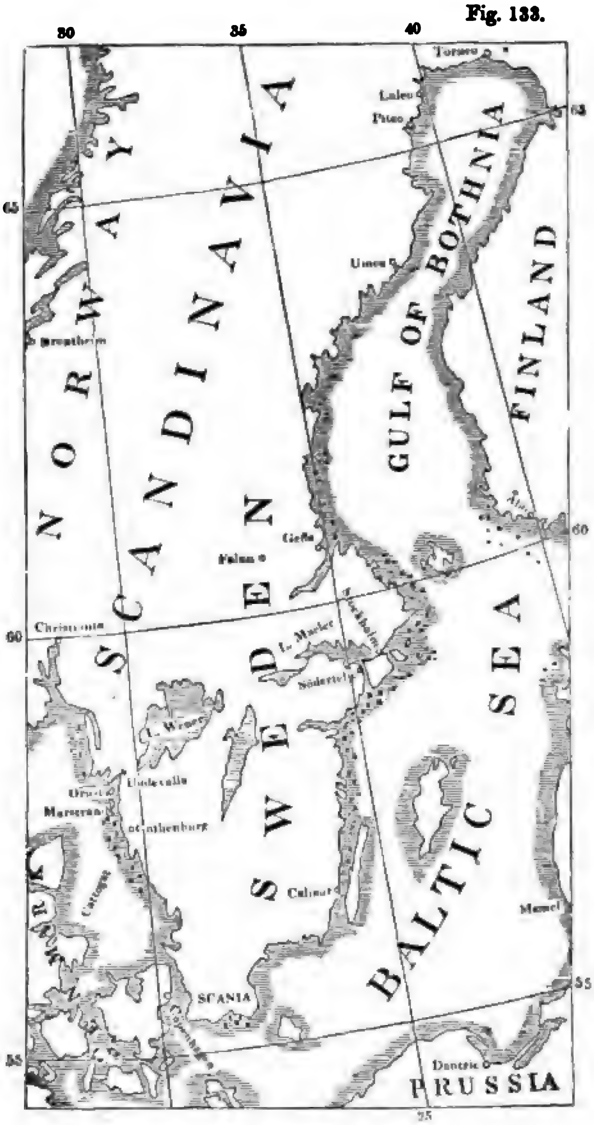
ice-islands float away, bearing up these rocky fragments so as to convey them to a distance; and if they are driven by the waves upon shoals, they may convert them into islands by depositing the blocks; if stranded upon low islands, they may considerably augment their height.

Browallius, also, and some other Swedish naturalists, affirmed that some islands were lower than formerly; and that, by reference to this kind of evidence, there was equally good reason for contending that the level of the Baltic was gradually rising. They also added another curious proof of the permanency of the water level, at some points at least, for many centuries. On the Finland coast were some large pines and oaks, growing close to the water's edge; these were cut down, and, by counting the concentric rings of annual growth, as seen in a transverse section of the trunk, it was demonstrated that some of them had stood there for nearly 400 years. Now, according to the Celsian hypothesis, the sea had sunk about 15 feet during that period, in which case the germination and early growth of these trees must have been, for many seasons, below the level of the water. In like manner, it was asserted that the lower walls of many ancient castles, such as those of Sonderburg and Åbo, reached then to the water's edge, and must, therefore, according to the theory of Celsius, have been originally constructed below the level of the sea.

In reply to this last argument, Colonel Hällstrom, a Swedish engineer, well acquainted with the Finland coast, assured me, that the base of the walls of the castle of Åbo is now ten feet above the water, so that there may have been a considerable rise of the land at that point since the building was erected. But the argument founded on the position of the trees is, as Professors Lovén and Erdmann have lately remarked, unanswerable so far as it relates to a part at least of the Finnish coast.

Playfair, in his 'Illustrations of the Huttonian Theory,' in 1802, admitted the sufficiency of the proofs adduced by Celsius, but attributed the change of level to the movement of the land, rather than to a diminution of the waters. He observed, 'that in order to depress or elevate the absolute

Fig. 133.



level of the sea, by a given quantity, in any one place, we must depress or elevate it by the same quantity over the whole surface of the earth; whereas no such necessity exists

with respect to the elevation or depression of the land.'* The hypothesis of the rising of the land, he adds, 'agrees well with the Huttonian theory, which holds that our continents are subject to be acted upon by the expansive forces of the mineral regions; that by these forces they have been actually raised up, and are sustained by them in their present situation.'†

In the year 1807, Von Buch, after returning from a tour in Scandinavia, announced his conviction, 'that the whole country, from Frederickshall in Norway to Åbo in Finland, and perhaps as far as St. Petersburg, was slowly and insensibly rising.' He also suggested 'that Sweden may rise more than Norway, and the northern more than the southern part.'‡ He was led to these conclusions principally by information obtained from the inhabitants and pilots respecting marks which had been set on the rocks, and partly by the occurrence of marine shells of recent species, which he had found at several points on the coast of Norway above the level of the sea. Von Buch, therefore, has the merit of being the first geologist who, after a personal examination of the evidence, declared in favour of the rise of land in Scandinavia.

The attention excited by this subject in the early part of the last century, had induced many philosophers in Sweden to endeavour to determine, by accurate observations, whether the standard level of the Baltic was really subject to periodical variations; and under their direction, lines or grooves, indicating the ordinary level of the water on a calm day, together with the date of the year, were chiselled out upon the rocks. In 1820–21, all the marks made before those years were examined by the officers of the pilotage establishment of Sweden; and in their report to the Royal Academy of Stockholm they declared, that on comparing the level of the sea at the time of their observations with that indicated by the ancient marks, they found that the Baltic was lower relatively to the land in certain places, but the amount of change during equal periods of time had not been everywhere

* Sect. 393. † Sect. 398. ‡ Transl. of his Travels, p. 387.

the same. During their survey, they cut new marks for the guidance of future observers, several of which I had an opportunity of examining fourteen years after (in the summer of 1834), and in that interval the land appeared to me to have risen at certain places north of Stockholm, as near Gefle, for example, about 4 inches, or at the rate of less than 2½ feet per century. But at Stockholm, I inferred from the position of certain aged oak-trees only 8 feet above the level of the Baltic, that the rise could not have been at a greater rate than 10 inches in a century, and might be less.* Professor Axel Erdmann in 1847 calculated that the rise could hardly have exceeded six inches at Stockholm, and in the same year he pointed out, in a paper read to the Royal Society of Sweden, the necessity of determining the mean level of the Baltic by a long series of observations in different seasons of the year. Mr. Wolfstedt, a Swedish engineer, has shown that the northern part of the Bothnian Gulf, where several great rivers enter, is 16 feet higher than the southern part; but as this gulf is about 600 miles in length, it will be seen that the rate of fall per mile according to this measurement is exceedingly small, so that the height of the water at corresponding seasons may vary but slightly, except when it is influenced by the wind. When I gave the results of my Swedish tour in the fourth edition of this work, published in 1835, I expressed my belief that there were signs of the upheaval of the land in different places visited by me, both on the coast of the Bothnian Gulf and on that of the ocean, i.e. the west coast of Sweden near Gothenburg. But I then stated that 'we have not only to learn whether the motion proceeds always at the same rate, but also whether it has been uniformly *in one direction*. The level of the land may oscillate; and for centuries there may be a depression, and afterwards a re-elevation, of the same district. Some phenomena in the neighbourhood of Stockholm appear to me only explicable on the supposition of the alternate rising and sinking of the ground since the country was inhabited by man. In digging a

* See a paper on 'Rise of Land in Sweden,' by the author. Phil. Trans. 1835, part i. p. 13—read in November 1834.

canal, in 1819, at Södertelje, about sixteen miles to the south of Stockholm, to unite Lake Maeler with the Baltic, marine strata, containing fossil shells of Baltic species, were passed through. At a depth of about 60 feet, they came down upon what seems to have been a buried fishing-hut, constructed of wood in a state of decomposition, which soon crumbled away on exposure to the air. The lowest part, however, which had stood on a level with the sea, was in a more perfect state of preservation. On the floor of this hut was a rude fireplace, consisting of a ring of stones, and within these were cinders and charred wood. On the outside lay boughs of the fir, cut as with an axe, with the leaves or needles still attached. It seems impossible to explain the position of this buried hut, without imagining, first, a subsidence to the depth of more than 60 feet, then a re-elevation. During the period of submergence, the hut must have become covered over with gravel and shelly marl, under which not only the hut, but several vessels also were found, of a very antique form, and having their timbers fastened together by wooden pegs instead of nails.'*

The investigations of MM. Lovén, Erdmann, Nordenskiöld, and others, made since my visit to Sweden in 1834, have on the whole tended to confirm the idea previously entertained, that some changes are now going on in the relative level of land and sea in certain parts of the Swedish coast, though they consider them to be probably local. With a view of accurately determining the reality of the movement, and its amount and direction, they have instituted a regular series of annual observations, which, however, have not yet been continued long enough to lead to positive results.

Lord Selkirk in 1866 re-examined many of the marks which I had seen, both in the Gulf of Bothnia and on the

* See my paper, before referred to, Phil. Trans. 1835, part i. pp. 8, 9. Attempts have been since made to explain away the position of this hut, by conjecturing that a more ancient trench had been previously dug here, which had become filled up in time by sand drifted by the wind. The engineers who superintended the works in 1819, and with whom I conversed, had considered every hypothesis of the kind, but could not so explain the facts.

Swedish coast near Gothenburg, in 1834. Among the former, the principal one, that of Löfgrund, near Gefle, seemed to indicate a fall of the water of about 9 inches in 32 years, which would give a rise of the land of between 2 and 3 feet in a century, as I had suggested; but other marks in the neighbourhood implied a smaller change of level. A line which I myself cut on a rock in the island of Gulholmen, off Oregrund, on the west coast, was found to be only 3 inches higher above the sea-level than when I made it. On the whole, after a comparison of this and various other marks, Lord Selkirk came to the conclusion, that, notwithstanding the absence of lunar tides both in the Baltic and on the west coast of Sweden near Gothenburg, there is so much fluctuation in the sea-level from day to day, owing to the action of the wind and other causes, that the observations of a casual visitor are of no real value in determining the average water-level.*

After a review of all that has been said and published on this subject since the commencement of the present century, I am inclined to believe, with the pilots, fishermen, and engineers, that a slow alteration in the relative level of land and sea is taking place along certain parts of the Swedish coast. This notion is not merely entertained by the inhabitants of those localities where rivers are carrying down sediment into the sea, but prevails equally in districts where the rocks for hundreds of miles plunge abruptly into deep water. It should be borne in mind, that, except near the Cattegat, there are no tides in the Baltic. It is only when particular winds have prevailed for several days in succession, or at certain seasons when there has been an unusually abundant influx of river-water, or when these causes have combined, that this sea is made to rise 2 or 3 feet above its standard level.

There are, moreover, peculiarities in the configuration of the shore which facilitate, in a remarkable degree, the appreciation of slight changes in the relative level of land and water. It has often been said, that there are two coasts,

* Lord Selkirk 'On some Sea-water Level Marks on the Coast of Sweden. Quart. Geol. Journ. 1867, p. 187.

an inner and an outer one; the inner being the shore of the mainland; the outer one, a fringe of countless rocky islands of all dimensions, called the skär (*shair*). Boats and small vessels make their coasting voyages within this skär; for here they may sail in smooth water, even when the sea without is strongly agitated. But the navigation is very intricate, and the pilot must possess a perfect acquaintance with the breadth and depth of every narrow channel, and the position of innumerable sunken rocks. If on such a coast the land rises 1 or 2 feet in the course of half a century, the minute topography of the skär is entirely altered. To a stranger, indeed, who revisits it after an interval of many years, its general aspect remains the same; but the inhabitant finds that he can no longer penetrate with his boat through channels where he formerly passed, and he can tell of countless other changes in the height and breadth of isolated rocks, now exposed, but once only seen through the clear water.

The rocks of gneiss, mica-schist, and quartz are usually very hard on this coast, slow to decompose, and, when protected from the breakers, remain for ages unaltered in their form. Hence it is easy to mark the stages of their progressive emergence by the aid of natural and artificial marks imprinted on them. Besides the summits of *fixed* rocks, there are numerous erratic blocks of vast size strewed over the shoals and islands in the skär, which have been probably drifted by ice in the manner before suggested.* All these are observed to have increased in height and dimensions within the last half-century. Some, which were formerly known as dangerous sunken rocks, are now only hidden when the water is highest. On their first appearance, they usually present a smooth, bare, rounded protuberance, a few feet or yards in diameter; and a single sea-gull often appropriates to itself this resting-place, resorting there to devour its prey. Similar points, in the meantime, have grown into long reefs, and are constantly whitened by a multitude of sea-fowl; while others have been changed from a reef,

* See p. 182; and Chap. XVI. Vol. I.

annually submerged, to a small islet, on which a few lichens, a fir-seedling, and a few blades of grass, attest that the shoal has at length been fairly changed into dry land. Thousands of wooded islands around show the greater alterations which time can work. In the course of centuries, also, the spaces intervening between the existing islands may be laid dry, and become grassy plains, encircled by heights well clothed with lofty firs. This last step of the process, by which long fiords and narrow channels, once separating wooded islands, are deserted by the sea, has been exemplified within the memory of living witnesses on several parts of the coast.

It was admitted on all hands when I visited Sweden, in 1834, that the supposed change in the relative level of sea and land was by no means going on at a uniform rate, or in a uniform direction, at all points between the North Cape and Scania, or the southernmost part of Sweden, places distant from each other more than 1,000 miles. The rate of upheaval was said to be greatest at the North Cape, but no accurate scientific proof of this fact has yet been obtained. At Gefle, 90 miles north of Stockholm, the movement may possibly, as before stated, amount to 2 or 3 feet in a century, whereas at Stockholm it can hardly exceed 6 inches. 16 miles to the south-west of Stockholm, at Södertelje, the land seems to have been quite stationary during the last century. Proceeding still farther south, the upward movement seems to give place to one in an opposite direction. In proof of this fact, Professor Nilsson has remarked, in the first place, that there are no elevated beds of recent marine shells in Scania, like those farther to the north. Secondly, Linnæus, with a view of ascertaining whether the waters of the Baltic were retiring from the Scanian shore, measured, in 1749, the distance between the sea and a large stone near Trelleborg. This same stone was, in 1836, a hundred feet nearer the water's edge than in Linnæus's time, or 87 years before. Thirdly, there is also a submerged peat moss, consisting of land and fresh-water plants, beneath the sea at a point to which no peat could have been drifted down by any river. Fourthly, and what is still more conclusive, it is found that in seaport

towns, all along the coast of Scania, there are streets below the high-water level of the Baltic, and in some cases below the level of the lowest tide. Thus, when the wind is high at Malmö, the water overflows one of the present streets, and some years ago some excavations showed an ancient street in the same place 8 feet lower, and it was then seen that there had been an artificial raising of the ground, doubtless in consequence of that subsidence. There is also a street at Trelleborg, and another at Skanör, a few inches below high-water mark, and a street at Ystad is exactly on a level with the sea, at which it could not have been originally built.

When we cross from the Gulf of Bothnia to the coast north of Gothenburg, we find that the opinion still prevails there, as it did in the days of Celsius, among the fishing and seafaring inhabitants, that there is a slow sinking of the sea going on; so that rocks, both on the shore of the mainland and in the islands, are more and more exposed to view. If this conclusion be confirmed by future observation, the breadth of the tract from WNW. to ESE., which is rising, must exceed 200 geographical miles, without including the bed of the two seas adjacent to the coasts.

Hitherto we have confined our attention almost exclusively to changes of level in historical times; but we may next enquire what geological proofs exist of the sojourn of the sea on the land, at a very modern period, in those parts of Sweden where there is ground for suspecting that a movement of elevation is in progress.

In this case, the evidence is most satisfactory. Near Uddevalla and the neighbouring coastland, we find upraised deposits of shells belonging to species such as now live in the ocean; while on the opposite or eastern side of Sweden, near Stockholm, Gefle, and other places bordering the Bothnian Gulf, there are analogous beds containing shells of species characteristic of the Baltic.

Von Buch announced in 1807, that he had discovered in Norway and at Uddevalla in Sweden, beds of shells of existing species, at considerable heights above the sea. Since that time, other naturalists have confirmed his observation; and, according to Torell, deposits occur at

elevations of 600 and even 700 feet above the sea in some parts of Norway. M. Alex. Brongniart, when he visited Uddevalla, ascertained that one of the principal masses of shells, that of Capellbacken, is raised more than 200 feet above the sea, resting on rocks of gneiss, all the species being identical with those now inhabiting the contiguous ocean. The same naturalist also stated, that on examining with care the surface of the gneiss, immediately above the ancient shelly deposit, he found barnacles (*balani*) adhering to the rocks, showing that the sea had remained there for a long time. I was fortunate enough to be able to verify this observation by finding in the summer of 1834, at Kured, about 2 miles north of Uddevalla, and at the height of more than 100 feet above the sea, a surface of gneiss newly laid open by the partial removal of a mass of shells used largely in the district for making lime and repairing the roads. So firmly did these barnacles adhere to the gneiss, that I was able to break off portions of the rock with the shells attached. The face of the gneiss was also encrusted with bryozoa; but had these or the barnacles been exposed to the atmosphere ever since the elevation of the rocks above the sea, they would doubtless have been decomposed and obliterated.

The town of Uddevalla (see Map, p. 184) stands at the head of a narrow creek overhung by steep and barren rocks of gneiss, of which all the adjacent country is composed, except in the low grounds and bottoms of valleys, where strata of sand, clay, and marl frequently hide the fundamental rocks. To these newer and horizontal deposits, sometimes 40 feet thick, the fossil shells above mentioned belong, and similar marine remains are found at about the same height above the sea on the opposite island of Orust, as well as in that of Tjörn, and at points near the coast still farther south.

Mr. J. Gwyn Jeffreys visited Uddevalla in 1862, and collected from the beds there 83 species of mollusca, characteristic of the Glacial Period. He also obtained evidence that a littoral and shallow-water deposit underlaid the shells proper to deeper water; a fact clearly implying a depression of the bed of the sea previous to that upheaval which has since carried

up the land where the marine shells are found, to the height of more than 200 feet.* As to the date of this last upheaval, Mr. Torell has shown that it by no means reaches back to the Glacial Period, to which the shells above alluded to belong. Those shells, so characteristic of a cold climate, are specifically identical with mollusca now living in the seas of Spitzbergen, 10 degrees of latitude north of Uddevalla. But in some recent deposits near Uddevalla, Mr. Torell detected, at the height of 200 feet above the sea, the remains of marine testacea, agreeing with species now proper to the fauna of the adjacent and more temperate sea.† It appears, therefore, that the series of movements in the district under consideration consisted, first, of a depression converting the shallow water into deep sea at a time when the cold was very severe, and then of an elevation of more than 200 feet when the waters of the sea had acquired their present milder temperature.

To return now to the coast of the Baltic. I observed near the shores of the Gulf of Bothnia, at Södertelje, 16 miles SW. of Stockholm, strata of sand, clay, and marl, more than 100 feet above the sea level, and containing shells of species now inhabiting the gulf. These consist partly of marine and partly of freshwater species; but though the individuals are numerous, the species are few in number, the brackish water appearing to be very unfavourable to the development of a rich and varied fauna. The most abundant species are the common cockle, mussel, and periwinkle of our shores (*Cardium edule, Mytilus edulis*, and *Littorina littorea*), together with a small tellina (*T. Baltica*, L.; *T. solidula*, Pult.), and a few minute univalves allied to *Paludina ulva*, which are still found living in that country associated with a *Lymnea*, a *Neritina* (*N. fluviatilis*), and some other freshwater shells.

But the marine mollusks of the Baltic above mentioned are dwarfish in size, scarcely ever attaining a third of the average dimensions which they acquire in the salter waters of the ocean. By this character alone a geologist would gene-

* Gwyn Jeffrey's Report to Brit. Assoc. 1863, p. 73.

† Torell, Beiträge, &c. Contributions to Molluscous Fauna of Spitzbergen, 1859.

rally be able to recognise at once an assemblage of Baltic fossils as distinguished from those derived from a deposit in the ocean. The absence also of oysters, barnacles, whelks, scallops, limpets (*ostrea, balanus, buccinum, pecten, patella*), and many other forms abounding alike in the sea near Uddevalla, and in the fossiliferous deposits of modern date on that coast, supplies an additional negative character of the greatest value, distinguishing assemblages of Baltic from those of oceanic shells. Now the strata containing Baltic shells are found in many localities near Stockholm, Upsala, and Gefle, and will probably be discovered everywhere around the borders of the Bothnian Gulf; for I have seen similar remains brought from Finland, in marl resembling that found near Stockholm. The utmost distance to which these deposits had been traced inland in 1835 was to a place 70 miles from the sea, on the southern shores of Lake Maeler, but they have since been traced by Erdmann to Linde, at the head of a lake of that name, to a distance of 130 miles west of Stockholm, and to a height of about 230 feet above the sea. Hence it appears, from the distinct assemblage of fossil shells found on the eastern and western coasts of Sweden, that the Baltic has been for a long period separated as now from the ocean, although the intervening tract of land was once much narrower, even after both seas had become inhabited by all the existing species of testacea.

Whether any of the land in Norway is now rising, must be determined by future investigations. Marine fossil shells, of recent species, have been collected from inland places near Drontheim; but Mr. Everest, in his 'Travels through Norway,' informs us that the small island of Munkholm, which is an insulated rock in the harbour of Drontheim, affords conclusive evidence of the land having in that region remained stationary for the last 8 centuries. The area of this isle does not exceed that of a small village; and by an official survey, its highest point has been determined to be 23 feet above the mean high-water mark, that is, the mean between neap and spring tides. Now, a monastery was founded there by Canute the Great, A.D. 1028, and 33 years before that time it was in use as a common place of execution.

According to the assumed average rate of rise in Sweden (about 40 inches in a century), we should be obliged to suppose that this island had been 3 feet 8 inches below high-water mark when it was originally chosen as the site of the monastery.

Professor Keilhau of Christiania, after collecting the observations of his predecessors respecting former changes of level in Norway, and combining them with his own, has made the fact of a general change of level at some unknown but, geologically speaking, modern period (that is to say, within the period of the actual testaceous fauna), very evident. He infers that the whole country from Cape Lindesnæs to the North Cape, and beyond that as far as the fortress of Vardhuus, has been gradually upraised, and on the south-east coast the elevation has amounted to more than 600 feet. The marks which denote the ancient coast-lines are so nearly horizontal, that the deviation from horizontality, although the measurements have been made at a great number of points, is too small to be appreciated.

More recently (1844), however, it appears from the researches of M. Bravais, member of the French Scientific Commission of the North, that in the Gulf of Alten in Finmark, the most northerly part of Norway lying to the north of Lapland, there are two distinct lines of upraised ancient sea-coast, one above the other, which are not parallel, and both of them imply that within a distance of 50 miles a considerable slope can be detected in such a direction as to show that the ancient shores have undergone a greater amount of upheaval in proportion as we advance inland.*

The different heights at which horizontal raised beaches containing recent shells have been observed along the western and northern coasts of Norway, have been supposed to prove the suddenness of the upheaval of the land at successive periods; but when truly interpreted, these appearances prove rather that the elevatory force has been intermittent in its action, and that there have been long pauses in the process

* Quarterly Journ. of Geol. Soc. No. 4, p. 534. M. Bravais' observations were verified in 1849 by Mr. R. Chambers in his 'Tracings of N. of Europe,' p. 208.

of upheaval. They mark eras at which the level of the sea has remained stationary for ages, and during which new strata were deposited near or on the shore in some places, while in others the waves and currents had time to hollow out rocks, undermine cliffs, and throw up long ranges of shingle. They undoubtedly show that the movement has not been always uniform or continuous, but they do not establish the fact of any sudden alterations of level.

Subsidence of part of Greenland.—The rise of Scandinavia has naturally been regarded as a very singular and scarcely credible phenomenon, because no region on the globe has been more free within the times of authentic history from violent earthquakes. In common, indeed, with our own island, and with almost every spot on the globe, movements have been, at different periods, experienced, both in Norway and Sweden. But some of these, as for example during the Lisbon earthquake in 1755, may have been mere vibrations or undulatory movements of the earth's crust prolonged from a great distance. Others, however, have been sufficiently local to indicate a source of disturbance immediately under the country itself. Notwithstanding these shocks, Scandinavia has, upon the whole, been as tranquil in modern times, and as free from subterranean convulsions, as any region of equal extent on the globe. The same may be said of another large area in Greenland, which in modern times has been undergoing a slow and insensible movement, but in an opposite direction. Two Danish investigators, Dr. Pingel and Captain Graah, have brought to light abundant evidence of the sinking down of part of the west coast of Greenland, for a space of more than 600 miles from north to south. The observations of Captain Graah were made during a survey of Greenland in 1823-24, and afterwards in 1828-29; those by Dr. Pingel were made in 1830-32. It appears from various signs and traditions, that the coast has been subsiding for the last 4 centuries from the firth called Igaliko, in lat. 60° 43′ N., to Disco Bay, extending to nearly the 69th degree of north latitude. Ancient buildings on low rocky islands and on the shore of the mainland have been gradually submerged, and experience

has taught the aboriginal Greenlander never to build his hut near the water's edge. In one place the Moravian settlers have been obliged more than once to move inland the poles upon which their large boats were set, and the old poles still remain beneath the water as silent witnesses of the change.*

The fact of the gradual elevation and depression of land throughout vast areas of Europe and Arctic America, which we have considered in this chapter, partly in the historical period and partly in geological times immediately antecedent, leads us naturally to speculate on the wonderful changes which must be continually in progress in the subterranean foundations of these same countries. Whether we ascribe these changes to the expansion of solid matter exposed to hydrothermal action, or to the melting of rock, or the solidification of mineral masses, in whatever conjectures we indulge, we cannot doubt that at some unknown depths the structure of the crust of our globe is gradually undergoing very important modifications.

* See Proceedings of Geol. Soc. No. 42, p. 208. I also conversed with Dr. Pingel on the subject at Copenhagen in 1834.

CHAPTER XXXII.

CAUSES OF EARTHQUAKES AND VOLCANOS.

INTIMATE CONNECTION BETWEEN THE CAUSES OF VOLCANOS AND EARTHQUAKES—SUPPOSED ORIGINAL STATE OF FUSION OF THE PLANET—ITS SIMULTANEOUS AND UNIVERSAL FLUIDITY NOT PROVED BY ITS SPHEROIDAL FIGURE—ATTEMPT TO CALCULATE THE THICKNESS OF THE SOLID CRUST OF THE EARTH BY PRECESSIONAL MOTION—HEAT OF EARTH'S CRUST INCREASING WITH THE DEPTH, BUT NOT EQUALLY—NO INTERNAL TIDES OF SUPPOSED CENTRAL FLUID PERCEPTIBLE—SUPPOSED CHANGE OF AXIS OF EARTH'S CRUST—PARTIAL FLUIDITY OF THE EARTH'S CRUST MOST CONSISTENT WITH VOLCANIC PHENOMENA OF THE PAST AND PRESENT—ABANDONMENT OF THE DATA BY WHICH THE EARLIER GEOLOGISTS SUPPORTED THEIR THEORY OF THE PRISTINE FLUIDITY OF THE EARTH'S CRUST—DOCTRINE OF A CONTINUAL DIMINUTION OF TERRESTRIAL AND SOLAR HEAT CONSIDRRED.

It will hardly be questioned, after the description before given of the phenomena of earthquakes and volcanos, that both of these agents have, to a certain extent, a common origin; and I may now, therefore, proceed to enquire into their probable causes. But, first, it may be well to recapitulate some of those points of relation and analogy which lead naturally to the conclusion that they spring from a common source.

The regions convulsed by violent earthquakes include within them the sites of all the active volcanos. Earthquakes, sometimes local, sometimes extending over vast areas, often precede volcanic eruptions. The subterranean movement and the eruption return again and again, at irregular intervals of time, and with unequal degrees of force, to the same spots. The action of either may continue for a few hours, or for several consecutive years. Paroxysmal convulsions are usually followed, in both cases, by long periods of tranquillity. Thermal and mineral springs are abundant in countries of earthquakes and active volcanos Lastly, springs situated in districts considerably distant

from volcanic vents have been observed to have their temperature suddenly raised or lowered, and the volume of their water increased or lessened, by subterranean movements.

All these appearances are evidently more or less connected with the passage of heat from the interior of the earth to the surface; and where there are active volcanos, there must exist, at some unknown depth below, enormous masses of matter intensely heated, and, in many instances, in a constant state of fusion. We have first, then, to enquire, whence is this heat derived?

Supposed central fluidity of the earth.—It has long been a favourite conjecture that the whole of our planet was originally in a state of igneous fusion, and that the central parts still retain a great portion of their primitive heat. Some have imagined, with the late Sir William Herschel, that the elementary matter of the earth may have been first in a gaseous state, resembling those nebulæ which we behold in the heavens, and which are of dimensions so vast that some of them would fill the orbits of the remotest planets of our system. The increased power of the telescope has of late years resolved the greater number of these nebulous appearances into clusters of stars; but so long as they were confidently supposed to consist of aëriform matter, it was a favourite conjecture that they might, if concentrated, form solid spheres; and it was also imagined that the evolution of heat, attendant on condensation, might retain the materials of the new globes in a state of igneous fusion.

Without dwelling on such speculations, which can only have a distant bearing on geology, we may consider how far the spheroidal form of the earth affords sufficient ground for presuming that its primitive condition was one of universal fluidity. The discussion of this question would be superfluous, were the doctrine of original fluidity less popular; for it may well be asked, why the globe should be supposed to have had a pristine shape different from the present one?—why the terrestrial materials, when first called into existence, or assembled together in one place, should not have been subject to rotation, so as to assume at once that form

which alone could retain their several parts in a state of equilibrium?

Let us, however, concede that the statical figure may be a modification of some other pre-existing form, and suppose the globe to have been at first a perfect and quiescent sphere, covered with a uniform ocean—what would happen when it was made to turn round on its axis with its present velocity? This problem has been considered by Playfair in his Illustrations; and he has decided, that if the surface of the earth, as laid down in Hutton's theory, has been repeatedly changed by the transportation of the detritus of the land to the bottom of the sea, the figure of the planet must in that case, whatever it may have been originally, be brought at length to coincide with the spheroid of equilibrium.* The late Sir John F. W. Herschel also, in reference to the same hypothesis, observes, 'A centrifugal force would in that case be generated, whose general tendency would be to urge the water at every point of the surface to *recede* from the *axis*. A rotation might indeed be conceived so swift as to flirt the whole ocean from the surface, like water from a mop. But this would require a far greater velocity than what we now speak of. In the case supposed, the *weight* of the water would still keep it *on* the earth; and the tendency to recede from the axis *could* only be satisfied therefore by the water leaving the poles, and flowing towards the equator; there heaping itself up in a ridge, and being retained in opposition to its weight or natural tendency towards the centre by the pressure thus caused. This, however, could not take place without laying dry the polar regions, so that protuberant land would appear at the poles, and a zone of ocean be disposed around the equator. This would be the first or immediate effect. Let us now see what would afterwards happen if things were allowed to take their natural course.'

'The sea is constantly beating on the land, grinding it down, and scattering its worn-off particles and fragments, in the state of sand and pebbles, over its bed. Geological facts afford abundant proof that the existing continents have

* Illust. of Hutt. Theory, § 435—443.

all of them undergone this process even more than once, and been entirely torn in fragments, or reduced to powder, and submerged and reconstructed. Land, in this view of the subject, loses its attribute of fixity. As a mass, it might hold together in opposition to forces which the water freely obeys; but in its state of successive or simultaneous degradation, when disseminated through the water, in the state of sand or mud, it is subject to all the impulses of that fluid. In the lapse of time, then, the protuberant land would be destroyed, and spread over the bottom of the ocean, filling up the lower parts, and tending continually to remodel the surface of the solid nucleus, in correspondence with the *form of equilibrium*. Thus, after a sufficient lapse of time, in the case of an earth in rotation, the polar protuberances would gradually be cut down and disappear, being transferred to the equator (as being *then* the *deepest sea*), till the earth would assume by degrees the form we observe it to have—that of a flattened or *oblate* ellipsoid.'

'We are far from meaning here to trace the process *by which* the earth really assumed its actual form; all we intend is to show that this is the form to which, under a condition of a rotation on its axis, it must *tend*, and which it would attain even if originally and (so to speak) perversely constituted otherwise.'*

Although in the above passage no mention is made of subaërial denudation, yet it must be understood that it would play a leading part in the degradation of the polar land under the condition above assumed. Sir John Herschel has also confined his observations to the effects of aqueous causes only; neither he nor Playfair seem to have followed out the same enquiry with reference to another part of Hutton's system; namely, that which assumes the successive fusion by heat of different parts of the solid earth. Yet the progress of geology has continually strengthened the evidence in favour of the doctrine that local variations of temperature have melted one part after another of the earth's crust, and this influence has perhaps extended downwards to the very centre. If,

* Herschel's Astronomy, chap. iii.; also 7th edition, chap. iv. p. 142.

therefore, before the globe had assumed its present form, it was made to revolve on its axis, all matter to which freedom of motion was given by fusion, must before consolidating have been impelled towards the equatorial regions in obedience to the centrifugal force. Thus, lava flowing out in superficial streams would have its motion retarded when its direction was towards the pole, accelerated when towards the equator; or if lakes and seas of lava existed beneath the earth's crust in equatorial regions, as probably now beneath the Peruvian Andes, the imprisoned fluid would force outwards and permanently upheave the overlying rocks. The statical figure, therefore, of the terrestrial spheroid (of which the longer diameter exceeds the shorter by about twenty-five miles), may have been the result of gradual and even of existing causes, and not of a primitive, universal, and simultaneous fluidity.*

Experiments made with the pendulum, and observations on the manner in which the earth attracts the moon, have shown that our planet is not an empty sphere, but, on the contrary, that its interior, whether solid or fluid, has a higher specific gravity than the exterior. It has also been inferred from certain inequalities in the moon's motion, that there is a regular increase in density from the surface towards the centre, and that the equatorial protuberance is continued inwards; that is to say, that layers of equal density are arranged elliptically, and symmetrically, from the exterior to the centre.

The mean density of the earth has been computed by Laplace to be about 5½, or more than 5 times that of water. Now the specific gravity of many of our rocks is from 2½ to 3, and the greater part of the metals range between that density and 21. Hence some have imagined that the terrestrial nucleus may be metallic—that it may correspond, for example, with the specific gravity of iron, which is about 7. But here a curious question arises in regard to the form which materials, whether fluid or solid, might assume, if subjected to the enormous pressure which must obtain at the

* See Hennessy, On Changes in Earth's Figure, &c. Journ. Geol. Soc. Dublin, 1849; and Proc. Roy. Irish Acad. vol. iv. p. 337.

earth's centre. Water, if it continued to decrease in volume according to the rate of compressibility deduced from experiment, would have its density doubled at the depth of 93 miles, and be as heavy as mercury at the depth of 362 miles. Dr. Young computed that, at the earth's centre, steel would be compressed into one-fourth, and stone into one-eighth of its bulk.* It is more than probable, however, that after a certain degree of condensation, the compressibility of bodies may be governed by laws altogether different from those which we can put to the test of experiment; but the limit is still undetermined, and the subject is involved in such obscurity, that we cannot wonder at the variety of notions which have been entertained respecting the nature and conditions of the central nucleus. Some have conceived it to be fluid, others solid; some have imagined it to have a cavernous structure, and have even endeavoured to confirm this opinion by appealing to observed irregularities in the vibrations of the pendulum in certain countries.

An attempt has been made by Mr. Hopkins to determine the least thickness which can be assigned to the solid crust of the globe, if we assume the whole to have been once perfectly fluid, and a certain portion of the exterior to have acquired solidity by gradual refrigeration. This result he has endeavoured to obtain by a new solution of the delicate problem of the precessional motion of the pole of the earth, caused, as before mentioned, p. 275, Vol. I., by the attraction of the sun and moon, and principally the moon, on the protuberant parts at the earth's equator; for if these parts were solid to a great depth, the motion thus produced would differ considerably from that which would exist if they were perfectly fluid, and incrusted over with a thin shell only a few miles thick. In other words, the disturbing action of the moon will not be the same upon a globe all solid and upon one nearly all fluid, nor will it be the same upon a globe in which the solid shell forms one-half of the mass, and another in which it forms only one-tenth.

Mr. Hopkins has, therefore, calculated the amount of

* Young's Lectures, and Mrs. Somerville's Connection of the Physical Sciences, p. 90.

precessional motion which would result if we assume the earth to be constituted as above stated; *i.e.* fluid internally, and enveloped by a solid shell; and he finds that the amount will not agree with the observed motion, unless the crust of the earth be of a certain thickness. In calculating the exact amount, some ambiguity arises in consequence of our ignorance of the effect of pressure in promoting the solidification of matter at high temperatures. The hypothesis least favourable for a great thickness is found to be that which assumes the pressure to produce no effect on the process of solidification. Even on this extreme assumption, the thickness of the solid crust must be nearly *four hundred miles*, and this would lead to the remarkable result that the proportion of the solid to the fluid part would be as 49 to 51, or, to speak in round numbers, there would be nearly as much solid as fluid matter in the globe. The conclusion, however, which Mr. Hopkins announces as that to which his researches have finally conducted him, is thus expressed: 'Upon the whole, then, we may venture to assert that the minimum thickness of the crust of the globe, which can be deemed consistent with the observed amount of precession, cannot be less than one-fourth or one-fifth of the earth's radius;' that is, from 800 to 1,000 miles.*

It will be remarked, that this is a *minimum*, and any still *greater* amount would be quite consistent with the actual phenomena; the calculations not being opposed to the supposition of the general solidity of the entire globe. Nor do they preclude us from imagining that great lakes and seas of melted matter may be distributed through a shell 400 or 800 miles thick, provided they be so inclosed as to move with it, whatever motion of rotation may be communicated by the attraction of the sun and moon. M. Delaunay, the eminent French astronomer, in his paper on the 'Hypothesis of the Internal Fluidity of the Terrestrial Globe,'† has brought forward some objections to the arguments advanced by Mr.

* Phil. Trans. 1839, and Researches in Physical Geology, 1st, 2nd, and 3rd series, London, 1839—1842; also on Phenomena and Theory of Volcanos, Report Brit. Assoc. 1847.

† Comptes Rendus for July 13, 1868.

Hopkins; but Sir William Thomson, after carefully considering these objections, states that the hypothesis of a viscous fluid assumed by M. Delaunay can be mathematically proved to be insufficient for the phenomena, which cannot, he believes, be accounted for unless the crust have a thickness of at least 2,000 or 2,500 miles, and a rigidity approaching that of a globe of solid glass.*

Rate of heat increasing with depth.—The hypothesis of internal fluidity calls for the more attentive consideration, as it has been found that the heat in mines augments in proportion as we descend. Observations have been made, not only on the temperature of the air in mines, but on that of the rocks, and on the water issuing from them. The mean rate of increase, calculated from the most careful experiments yet made in 2 shafts, one near Durham, and another near Manchester, each of them 2,000 feet deep, is 1° Fahrenheit for every increase of depth of from 65 to 70 feet, a rate of increase considerably less than that previously deduced from coal-mines in the same districts.† This rate, however, agrees very nearly with previous observations made in several of the principal lead and silver mines in Saxony, which gave 1° Fahr. for every 65 feet. In this case, the bulb of the thermometer was introduced into cavities purposely cut in the solid rock at depths varying from 200 to about 900 feet. But in other mines of the same country, it was necessary to descend thrice as far for each degree of temperature.‡

A thermometer was fixed in the rock of the Dolcoath mine, in Cornwall, by Mr. Fox, at the great depth of 1,380 feet, and frequently observed during 18 months; the mean temperature was 68° Fahr., that of the surface being 50°, which gives 1° for every 75 feet.

Kupffer, after an extensive comparison of the results in different countries, makes the increase 1° Fahr. for about every 37 English feet.§ M. Cordier announces, as the result

* Nature, Vol. V., January 18, 1872, p. 223, and Feb. 1st, p. 257.

† These observations were made by Professor Philips.

‡ Cordier, Mém. de l'Instit. tom vii.

§ Pog. Ann. tom. xv. p. 159.

of his experiments and observations on the temperature of the interior of the earth, that the heat increases rapidly with the depth; but the increase does not follow the same law over the whole earth, being twice or three times as much in one country as in another, and these differences are not in constant relation either with the latitudes or longitudes of places. He is of opinion, however, that the increase would not be overstated at 1° Cent. for every 25 mètres, or about 1° Fahr. for every 45 feet.* The experimental well bored at Grenelle, near Paris, gave, as before stated (Vol. I. p. 387), an increase of about 1° Fahr. for every 60 English feet to the depth of 1,800 feet.

At Naples, according to Mr. Mallet, the water in the Artesian well at the Royal Palace, at the depth of 1,460 feet, has a temperature of only 68° Fahr., which, deducting for the mean temperature of the surface soil, 61° Fahr., gives an increment of only 1° Fahr. for every 208 feet in depth. Another well in the same city, only a mile distant from the former and 909 feet deep, gives 1° Fahr. for 83 feet in depth. It is conjectured that the low temperature of the well first mentioned may be due to the cooling influence both of fresh and sea water which may be filtered through porous beds of tufa.

Some writers have endeavoured to refer these phenomena (which, however discordant as to the ratio of increasing heat, appear all to point one way) to the condensation of air constantly descending from the surface into the mines. For the air under pressure would give out latent heat, on the same principle as it becomes colder when rarefied in the higher regions of the atmosphere. But the argument has been answered in a satisfactory manner by Mr. Fox, who has shown, from observations made in the mines of Cornwall, that the difference of temperature between the descending and ascending currents varies from 9° to 17° Fahr., and therefore that the accession of heat is greater than could be supposed to be caused by the condensation of the air.†

* See M. Cordier's Memoir on the Temperature of the Interior of the Earth, June, 1827. Mém. de l'Instit. tom. vii., and Edin. New Phil. Journal, No. viii. p. 273.

† Phil. Mag. and Ann. Feb. 1830.

If we adopt the mean increase of 1° Fahr. for every 65 feet of depth, and assume, with the advocates of central fluidity, that the increasing temperature is continued downwards for an indefinite distance, we should reach the ordinary boiling point of water at rather more than 2 miles below the surface, and at the depth of about 34 miles should arrive at the melting point of iron, or 2,786° Fahr. according to Daniell's pyrometer, a heat sufficient to fuse almost every known substance. In the diagram, fig. 134, p. 212, the outer circular line represents a thickness of 25 miles, and the space between the 2 circles, together with the lines themselves, represents a crust of 200 miles in depth. If, therefore, the heat went on increasing at the rate above alluded to, we should encounter not far below the outer line a temperature many times greater than that sufficient to melt the most refractory substances known to us. At much greater depths, and long before approaching the central nucleus, the heat would be so intense (160 times that of melted iron), that we cannot conceive the external crust to resist fusion.*

It may be said that we may stand upon the hardened surface of a lava current while it is still in motion—nay, may descend into the crater of Vesuvius after an eruption, and stand on the scoriæ while every crevice shows that the rock is red-hot 2 or 3 feet below us; and at a somewhat greater depth, all is, perhaps, in a state of fusion. May not, then, a much more intense heat be expected at the depth of several hundred yards or miles? The answer is—that until a great quantity of heat has been given off, either by the emission of lava, or in a latent form by the evolution of steam and gas, the melted matter continues to boil in the crater of a volcano. But ebullition ceases when there is no longer a sufficient supply of heat from below, and then a crust of lava may form on the top, and showers of scoriæ

* The expansion of platinum was the test employed by Mr. Daniell in his pyrometer, which was found to yield uniform and constant results, in harmony with those derived from other independent sources. But Dr. Percy informs me that neither this nor any other test yet invented for measuring intense heat can be fully depended upon. Malleable iron, he remarks, requires more heat for its fusion than wrought iron, in which the metal is mixed with a small percentage of carbon.

may then descend upon the surface, and remain unmelted. If the internal heat be raised again, ebullition will recommence, and soon fuse the superficial crust. So in the case of the moving current, we may safely assume that no part of the liquid beneath the hardened surface is much above the temperature sufficient to retain it in a state of fluidity.

M. Poisson, in his Mathematical Theory of Heat, published in 1835, controverted the doctrine of the high temperature of a central nucleus, and declared his opinion that if the globe had ever passed from a liquid to a solid state in consequence of the loss of heat by radiation, the cooling and consolidation of the nucleus would have begun at the earth's centre.

Many of the advocates of central fluidity have admitted that there must be tides in the internal ocean; but their effect, says Cordier, has become feeble, although originally, when the fluidity of the globe was perfect, 'the rise and fall of these ancient land tides could not have been less than from 13 to 16 feet.' Now, granting for a moment that these tides have become so feeble as to be incapable of causing the fissured shell of the earth to be first uplifted and then depressed every 6 hours, still may we not ask whether, in every volcano during an eruption, the lava, which is supposed to communicate with a great central ocean, would not rise and fall sensibly, or whether, in a crater like Stromboli, where there is always melted matter in a state of ebullition, the ebbing and flowing of the liquid would not be constant?

Supposed change of axis of earth's crust.—An ingenious paper was read before the Royal Society,* by Mr. Evans in 1866, in which he suggested that former changes of climate on the surface might be connected with the sliding of a solid shell over an internal fluid nucleus. Granting for the moment the fluidity (in spite of the arguments I have adduced against it, p. 204), the equilibrium of the external shell might, no doubt, be disturbed by the transfer of the sediment from one part of the surface to another, or by the upheaval of new continents and islands; and Mr. Evans shows that, whenever matter is abstracted from one part and added to another, the centrifugal force of the augmented extraneous matter would

* J. Evans, Royal Society Proceedings, 1866.

tend to draw over the shell towards the equator, or an opposite effect would be produced if the surface was relieved of part of its weight, in which case the lighter part would move towards the pole.

Newton, and afterwards Laplace, had argued against the probability of a shifting of the earth's axis of rotation, and more recently Mr. Airy had among other arguments pointed out that the elevation of mountain chains at certain geological periods, which had been proposed as causing an alteration in the earth's centre of gravity, was an insignificant cause, since the size of such mountain masses was very minute, when compared to the equatorial protuberance, which he says is a mass of matter 25,000 miles long, 6,000 miles broad, and 13 miles deep. But Mr. Evans suggests that the axis of rotation of the nucleus might remain unchanged, while a solid shell not more, perhaps, than 25 miles in thickness might have its axis of rotation altered. To this hypothesis there are several objections:—

First, in all geological times, the transfer of sediment has been taking place not only from higher to lower latitudes, but also from lower to higher. There is the like tendency in the various elevations and depressions of land simultaneously in progress to balance each other. It is only the excess of alteration in one direction that can be available as a disturbing cause, and we can hardly imagine this excess to be important enough to cause a sensible change in the axis of rotation even of the external shell, such as might explain the altered climate of the same country in successive geological periods.

Secondly, a greater difficulty arises out of the fact that the earth is a spheroid and not a perfect sphere, since it becomes necessary to imagine the fluidity of the nucleus to be so perfect as to allow the shell to slide freely over it. If the lower or inner surface of the envelope be irregular in shape, or if it be even viscous in part, great resistance would be offered to any change in its position. Its freedom of motion would be checked by its not fitting the nucleus, let its change of position be ever so slight, and this change

could only be effected by the most violent friction, attended by the bending and rending of the incumbent mass.

Partial fluidity of the earth's crust most consistent with volcanic phenomena.—It must not be forgotten that the geological speculations still in vogue respecting the original fluidity of the planet, and the gradual consolidation of its external shell, belong to a period when theoretical ideas were entertained as to the relative age of the crystalline foundations of that shell wholly at variance with the present state of our knowledge. It was formerly imagined that all granite was of very high antiquity, and that rocks such as gneiss, mica-schist, and clay slate, were also anterior in date to the existence of organic beings on a habitable surface. It was, moreover, supposed that these primitive formations, as they were called, implied a continual thickening of the crust at the expense of the original fluid nucleus. These notions have been universally abandoned. It is now ascertained that the granites of different regions are by no means all of the same antiquity, and that it is hardly possible to prove any one of them to be as old as the oldest known fossil organic remains. It is likewise now admitted, that gneiss and other stratified crystalline strata are sedimentary deposits which have undergone metamorphic action, and they can almost all be demonstrated to be newer than the lately discovered fossil called Eozoon Canadense. It follows from such views, which are of comparatively modern date, that instead of these crystalline rocks, which are often of enormous volume, implying a constant thickening of the earth's crust from the remotest periods, they most of them bear testimony to aqueous denudation on a vast scale, or, in other words, they bespeak the removal of just as much solid matter from one part of the earth's circumference as has been contemporaneously accumulated in the shape of new strata in some other part. It was, moreover, taken for granted by the earlier theorists, without any sufficient geological proof, that the energy of the volcanic force was far more intense in the remoter periods of the earth's history than in the later. No adequate conception had been formed of the great lapse of time occupied in the elaboration of each of the principal groups of

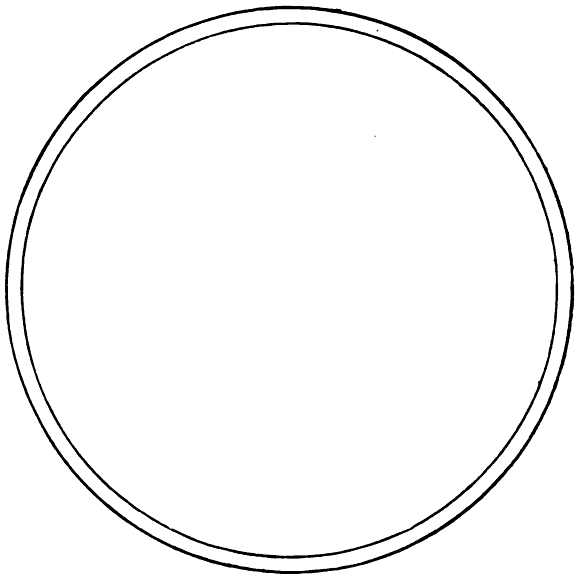
the primary, secondary, and tertiary fossiliferous rocks, and of the gradual manner in which contemporaneous volcanic products were locally developed during each of those periods.

The limited areas to which the volcanic outbursts were confined at any one epoch, the Cretaceous for example, are proved by the general absence in strata of the same age of associated igneous formations. It can be demonstrated that the volcanic power was by no means dormant, but it was locally developed. There are wide tracts in North America and Russia where very ancient strata, such as the Silurian and Carboniferous, are horizontal and undisturbed, and wholly devoid of contemporaneous igneous products, showing that such areas were not only free from volcanic action in Palæozoic times, but that they have never been the theatres of such action at any subsequent epoch. On the other hand, we often find that regions where showers of volcanic ashes and the intrusion of igneous matter into fissures were once most frequent, are now entirely free from volcanic disturbance. The continual transfer, therefore, of the points of chief development of the earthquake and volcano from one part of the earth's crust to another, is established as a general law by the clearest geological evidence. We have also seen (Chapter XXIII.) that volcanic operations are now in progress on the grandest scale, and also that single currents of lava of modern date are as voluminous as any which can be shown to have ever poured out in the earliest eras to which our geological retrospect can be carried.

The doctrine, therefore, of the pristine fluidity of the interior of the earth, and of the gradual solidification of its crust consequent on the loss of internal heat by radiation into space, is one of many scientific hypotheses, which has been adhered to after the props by which it was at first supported have given way one after another. The astronomer may find good reasons for ascribing the earth's form to the original fluidity of the mass in times long antecedent to the first introduction of living beings into the planet; but the geologist must be content to regard the earliest monuments which it is his task to interpret as belonging to a period when the crust had already acquired great solidity and thickness, probably as great as

it now possesses, and when volcanic rocks not essentially differing from those now produced were formed from time to time, the intensity of volcanic heat being neither greater nor less than it is now. This heat has, no doubt, given rise at successive periods to many of the leading changes in the form and structure of the earth's crust; but their magnitude is by no means such as to warrant our invoking the igneous fusion of the whole planet to account for them. If the reader will refer to the accompanying diagram, fig. 134, he may

Fig. 134.



Section of the earth in which the breadth of the outer boundary line represents a thickness of 25 miles; the space between the circles, including the breadth of the lines, 200 miles.

convince himself that a machinery more utterly disproportionate to the effects which it is required to explain was never appealed to. The outer circular line of the diagram represents a portion of the earth's diameter equal to 25 miles; so that if the loftiest mountain chains, even such as the Himalaya, 5 miles in their greatest height, could be expressed by white marks within this line, they would form a feature in it which would be scarcely appreciable.

The space between the two circles, including the thickness of the lines themselves, has a breadth or diameter of 200 miles. Let us, then, suppose very thin lines 2 inches long, and equal in width to only $\frac{1}{4}$ of the outer line, to be drawn here and there within this crust of 200 miles in thickness. These lines, faint and unimportant as they would appear, might nevertheless represent sections of seas or oceans of melted lava 5 miles deep and 5,000 miles long. It cannot be denied that the expansion, melting, solidification and shrinking of such subterranean seas of lava at various depths, might suffice to cause great movements or earthquakes at the surface, and even great rents in the earth's crust several thousand miles long, such as may be implied by the lineally arranged cones of the Andes or mountain chains like the Alps.

Supposed secular loss of heat in the solar system.—It is a favourite dogma of some physicists, that not only the earth but the sun itself is continually losing a portion of its heat, and that as there is no known source by which it can be restored, we can foresee the time when all life will cease to exist upon this planet, and on the other hand we can look back to the period when the heat was so intense as to be incompatible with the existence of any organic beings such as are known to us in the living or fossil world.

I shall consider in the next chapter the connection of solar and terrestrial magnetism, and the extent to which electricity may be conceived to be a source of volcanic heat. But when we consider the discoveries recently made of the convertibility of one kind of force into another, and how light, heat, magnetism, electricity, and chemical affinity are intimately connected, we may well hesitate before we accept the theory of the constant diminution from age to age of a great source of dynamical and vital power. 'All reflecting minds are now convinced,' says Mr. Grove, 'that force cannot be annihilated. If light, then, is lost as light (and the observations of Struvé seem to show this to be so—that, in fact, a star may be so far distant that it can never be seen in consequence of its luminous emissions becoming extinct), what becomes of the transmitted force lost as light, but ex-

isting in some other form? So with heat; our sun, our earth, and planets are constantly radiating heat into space, so, in all probability, are the other suns, the stars, and their attendant planets. What becomes of the heat thus radiated into space? If the universe have no limit, and it is difficult to conceive one, there is a constant evolution of heat and light; and yet more is given off than is received by each (self-luminous) cosmical body, for otherwise night would be as light and as warm as day. What becomes of the enormous force thus apparently non-recurrent in the same form? Does it return as palpable motion? Does it move or contribute to move suns and planets? and can it be conceived as a force similar to that which Newton speculated on as universally repulsive and capable of being substituted for universal attraction?' * A geologist, in search of some renovating power, by which the amount of heat may be made to continue unimpaired for millions of years, past and future, in the solid parts of the earth, although perpetually shifting the chief points of its development, has been compared to one who dreams he can discover a source of perpetual motion, and invent a clock with a self-winding apparatus. But why should we despair of detecting proofs of such a regenerating and self-sustaining power in the works of a Divine Artificer? What is the origin of the force which governs the motions of the heavenly bodies? It has been likened to the intellectual power of the human will, which initiates and directs all our muscular actions. To define its nature, has hitherto baffled the efforts of the metaphysician and natural philosopher, but assuredly we are not yet so far advanced in our knowledge of the system of the universe as to be entitled to declare that a great dynamical force like that of heat is on the wane.

* British Assoc. Address, Nottingham, August 22 1866.

CHAPTER XXXIII.

CAUSES OF EARTHQUAKES AND VOLCANOS—*continued.*

AGENCY OF STEAM IN VOLCANIC ERUPTIONS—GEYSERS OF ICELAND—NEW ZEALAND GEYSERS—EXPANSIVE POWER OF LIQUID GASES—ACCESS OF SALT WATER, ATMOSPHERIC AIR, AND FRESH WATER TO THE VOLCANIC FOCI—HOW THE SUCCESSIVE DEVELOPMENT OF VOLCANIC HEAT IN THE EARTH'S CRUST CAUSES IT TO RESEMBLE A BODY COOLING FROM A GENERAL STATE OF FUSION—FLEXIBILITY OF THE EARTH'S CRUST—ELECTRICITY AND MAGNETISM CONSIDERED AS SOURCES OF VOLCANIC HEAT—CHEMICAL ACTION—CAUSES OF PERMANENT ELEVATION AND SUBSIDENCE OF LAND—BALANCE OF DRY LAND, HOW PRESERVED—RECAPITULATION OF CHAPTERS XXXII. AND XXXIII.

Agency of steam in volcanic eruptions.—We have seen that almost all the active volcanos are on sea-coasts or in islands. 'Out of 225 volcanos,' says Sir John Herschel, 'which are known to have been in eruption within the last 150 years, there is only a single instance of one more than 320 miles from the sea, and even that one, Mount Demawend in Persia, is on the edge of the Caspian, the largest of all the inland seas.' Jorullo in Mexico, which was in eruption in 1759, is no less than 120 miles from the nearest ocean; but, as Dr. Daubeny observes, it forms part of a train of volcanos one extremity of which is near the sea. (See Vol. I. p. 585, and Chap. XXVII. Vol. II. p. 53.) The volcano said to have been in activity in the 7th century in Central Tartary is 260 geographical miles from the ocean, but near a large lake. (Vol. I. p. 592.)

Mr. Dana, in his valuable and original observations on the volcanos of the Sandwich Islands, reminds us of the prodigious volume of atmospheric water which must be absorbed into the interior of such large and lofty domes, composed as they are entirely of porous lava. To this source alone he refers the production of the steam by which the melted matter

is propelled upwards, even to the summit of cones 3 miles in height.*

Geysers of Iceland.—The extent to which porous rocks are percolated by rain-water to great depths in almost every region, however far from the sea, has been alluded to in our chapter on Springs (Vol. I. p. 384); and as there is no doubt that ordinary steam plays a prominent part in volcanic eruptions generally, it may be well before going farther to consider attentively a case in which we know it to be exclusively the moving power, namely, that of the Geysers of Iceland. These intermittent hot springs occur in a district situated in the south-western division of Iceland, where nearly 100 of them are said to break out within a circle of 2 miles. That the water is of atmospheric origin, derived from rain and melted snow, is proved, says Professor Bunsen, by the nitrogen which rises from them either pure or mixed with other gases. The springs rise through a thick current of lava, which may perhaps have flowed from Mount Hecla, the summit of that volcano being seen from the spot at the distance of more than 30 miles. In this district the rushing of water is sometimes heard in chasms beneath the surface; for here, as on Etna, rivers flow in subterranean channels through the porous and cavernous lavas. It has more than once happened, after earthquakes, that some of the boiling fountains have increased or diminished in violence and volume, or entirely ceased, or that new ones have made their appearance—changes which may be explained by the opening of new rents and the closing of pre-existing fissures.

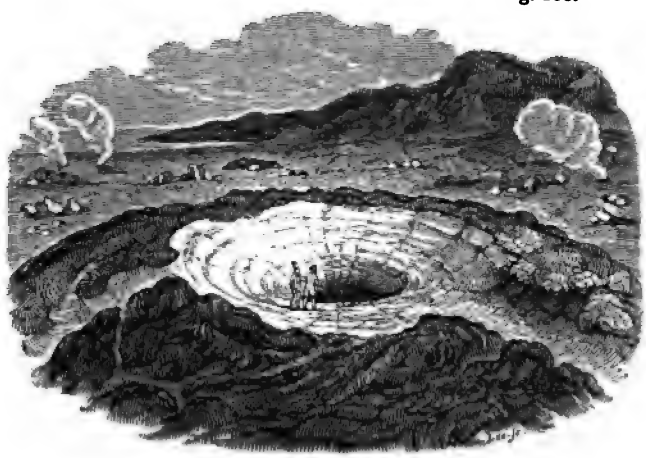
Few of the Geysers play longer than 5 or 6 minutes at a time, although sometimes half an hour. The intervals between their eruptions are for the most part very irregular. The Great Geyser rises out of a spacious basin at the summit of a circular mound composed of siliceous incrustations deposited from the spray of its waters. The diameter of this basin, in one direction, is 56 feet, and 46 in another. (See fig. 135.)

In the centre is a pipe 78 feet in vertical depth, and

* Geology of American Exploring Expedition, p. 369.

from 8 to 10 feet in diameter, but gradually widening as it rises into the basin. The inside of the basin is whitish, consisting of a siliceous crust, and perfectly smooth, as are likewise two small channels on the sides of the mound, down which the water escapes when the bowl is filled to the margin. The circular basin is sometimes empty, as represented in the following sketch; but is usually filled with beautifully transparent water in a state of ebullition. During the rise of the boiling water in the pipe, especially when the

Fig. 135.



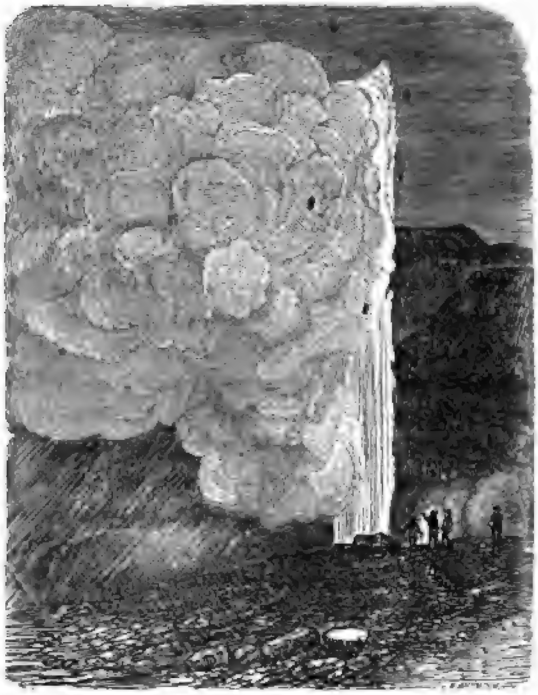
View of the crater of the Great Geyser in Iceland.

ebullition is most violent, and when the water is thrown up in jets, subterranean noises are heard, like the distant firing of cannon, and the earth is slightly shaken. The sound then increases, and the motion becomes more violent, till at length a column of water is thrown up, with loud explosions, to the height of 100 or 200 feet. After playing for a time like an artificial fountain, and giving off great clouds of vapour, the pipe or tube is emptied; and a column of steam, rushing up with amazing force and a thundering noise, terminates the eruption.

If stones are thrown into the crater, they are instantly ejected; and such is the explosive force, that very hard rocks are sometimes shivered by it into small pieces. Henderson found that by throwing a great quantity of large stones into

the pipe of Strokkur, one of the Geysers, he could bring on an eruption in a few minutes.* The fragments of stone, as well as the boiling water, were thrown in that case to a much greater height than usual. After the water had been ejected, a column of steam continued to rush up with a deafening roar for nearly an hour; but the Geyser, as if exhausted by this effort, did not send up a fresh eruption when its usual

Fig. 136.



Eruption of the New Geyser in 1810. (Mackenzie.)

interval of rest had elapsed. The account given by Sir George Mackenzie of a Geyser which he saw in eruption in 1810 (see fig. 136), agrees perfectly with the above description by Henderson. The steam and water rose for half an hour to the height of 70 feet, and the white column remained vertical notwithstanding a brisk gale of wind which was blowing against it. Stones thrown into the pipe were pro-

* Journal of a Residence in Iceland, p. 74.

jected to a greater height than the water. To leeward of the vapour, a heavy shower of rain was seen to fall.*

New Zealand Geysers.—The Geysers of New Zealand, although they have hitherto attracted less notice, are quite as numerous and remarkable as those of Iceland. They occur in thousands on the Northern Island, forming three parallel lines striking in the direction of N. 36° E. In a valley called Orakeikorako, on the river Waikato, Dr. Hochstetter counted 76 points of eruption in view at one time, many of them forming intermittent geyser-like fountains, with periodical water eruptions. The phenomena exhibited by these hot springs are throughout similar to those of Iceland, and the incrustations deposited by them are, in like manner, siliceous, and not calcareous. The intermittent springs, called by the natives Puias, which at certain periods give forth regular geyser-like water eruptions, form a class quite distinct from the Ngawhas, or permanent springs, the surface of which either remains in a state of repose, or in uniform ebullition; but both kinds owe their origin, says Dr. Hochstetter, to the water permeating the surface and sinking into the bowels of the earth, where it becomes heated by volcanic fires.†

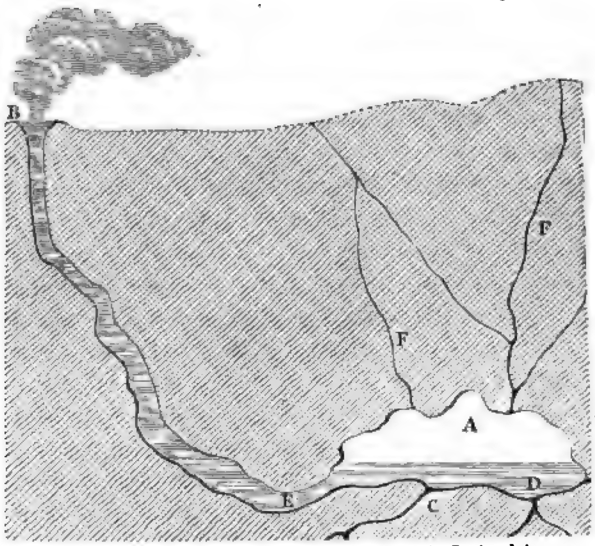
Causes of Geysers.—Among the different theories proposed to account for the phenomena of Geysers, I shall first mention one suggested by Sir J. Herschel. An imitation of these jets, he says, may be produced on a small scale, by heating red-hot the stem of a tobacco pipe, filling the bowl with water, and so inclining the pipe as to let the water run through the stem. Its escape, instead of taking place in a continued stream, is then performed by a succession of violent explosions, at first of steam alone, then of water mixed with steam; and, as the pipe cools, almost wholly of water. At every such paroxysmal escape of the water, a portion is driven back, accompanied with steam, into the bowl. The intervals between the explosions depend on the heat, length, and inclination of the pipe; their continuance, on its thickness and conducting

* Mackenzie's Iceland.

† Hochstetter, New Zealand, 1867, p. 432.

power.* The application of this experiment to the Geysers merely requires that a subterranean stream, flowing through the pores and crevices of lava, should suddenly reach a fissure, around which the rock is red-hot or nearly so. Steam would immediately be formed, which, rushing up the fissure, might force up water along with it to the surface, while, at the same time, part of the steam might drive back the water of the supply for a certain distance towards its source. And when, after the space of some minutes, the steam was all

Fig. 137.



Supposed reservoir and pipe of a Geyser in Iceland.†

condensed, the water would return, and a repetition of the phenomena take place.

There is, however, another mode of explaining the action of the Geyser, perhaps more probable than that above described. Suppose water percolating from the surface of the earth to penetrate into the subterranean cavity A D (fig. 137) by the fissures F F, while, at the same time, steam at an extremely high temperature, such as is commonly given out from the rents of lava currents during congelation, emanates from the fissures C. A portion of the steam is at first con-

* MS. read to Geol. Soc. of London, Feb. 29, 1832.

† From Sir George Mackenzie's Iceland.

densed into water, while the temperature of the water is raised by the latent heat thus evolved, till, at last, the lower part of the cavity is filled with boiling water and the upper with steam under high pressure. The expansive force of the steam becomes, at length, so great, that the water is forced up the fissure or pipe E B, and runs over the rim of the basin. When the pressure is thus diminished, the steam in the upper part of the cavity A expands, until all the water D is driven into the pipe; and when this happens, the steam, being the lighter of the two fluids, rushes up through the water with great velocity. If the pipe be choked up artificially, even for a few minutes, a great increase of heat must take place; for it is prevented from escaping in a latent form in steam; so that the water is made to boil more violently, and this brings on an eruption.

Professor Bunsen, before cited, adopts this theory to account for the play of the 'Little Geyser,' but says it will not explain the phenomena of the Great one. He considers this, like the others, to be a thermal spring, having a narrow funnel-shaped tube in the upper part of its course, where the walls of the channel have become coated over with siliceous incrustations. At the mouth of this tube the water has a temperature, corresponding to the pressure of the atmosphere, of about 212° Fahr., but at a certain depth below it is much hotter. This the Professor succeeded in proving by experiment; a thermometer suspended by a string in the pipe rising to 260° Fahr., or no less than 48° above the boiling point of ordinary atmospheric pressure. After the column of water has been expelled, what remains in the basin and pipe is found to be much cooled.*

Previously to these experiments of Bunsen and Descloizeaux, made in Iceland in 1846, it would scarcely have been supposed possible that the lower part of a free and open column of water could be raised so much in temperature without causing a circulation of ascending and descending currents, followed by an almost immediate equalisation of heat. Such circulation is no doubt impeded greatly by the sides of the well not being vertical, and by numerous contractions of its diameter,

* Bunsen. Poggendorf, Annalen der Physik, vol. lxxii.

but the phenomenon may be chiefly due to another cause. According to experiments on the cohesion of liquids by Mr. Donny of Ghent, it appears that when water is freed from all admixture of air, its temperature can be raised, even under ordinary atmospheric pressure, to 275° Fahr., so much does the cohesion of its molecules increase* when they are not separated by particles of air. As water long boiled becomes more and more deprived of air, it is probably very free from such intermixture at the bottom of the Geysers.

Among other results of the experiments of Bunsen and his companion, they convinced themselves that the column of fluid filling the tube is constantly receiving accessions of hot water from below, while it becomes cooler above by evaporation on the broad surface of the basin. They also came to a conclusion of no small interest, as bearing on the probable mechanism of ordinary volcanic eruptions, namely, that the tube itself is the main seat or focus of mechanical force. This was proved by letting down stones suspended by strings to various depths. Those which were sunk to considerable distances from the surface were not cast up again when the next eruption of the Geyser took place, whereas those nearer the mouth of the tube were ejected to a height of 100 feet. Other experiments also were made, tending to demonstrate the singular fact, that there is often scarcely any motion below, when a violent rush of steam and water is taking place above. It seems that when a lofty column of water possesses a temperature increasing with the depth, any slight ebullition or disturbance of equilibrium in the upper portion may first force up water into the basin, and then cause it to flow over the edge. A lower portion, thus suddenly relieved of part of its pressure, expands and is converted into vapour more rapidly than the first, owing to its greater heat. This allows the next subjacent stratum, which is much hotter, to rise and flash into a gaseous form, and this process goes on till the ebullition has descended from the middle to near the bottom of the funnel.†

* See Mr. Horner's Anniversary Address, Quart. Journ. Geol. Soc. 1847, liii.

† Liebig's Annalen der Chimie und Pharmacie, translated in 'Reports and Memoirs' of Cavendish Soc. London, 1848, p. 351.

Dr. Tyndall has produced a most perfect artificial representation of this process by heating from below a tube of galvanized iron filled with water, the mouth of the tube being made to pass upwards into a basin. As soon as the water becomes heated near enough to the boiling point it is ejected into the atmosphere, and this continues regularly at intervals of five minutes, the supply being kept up as in the real Geyser by the falling back of the cooled water into the tube. By stopping the mouth of the tube with a cork, and thus causing the heat to accumulate more rapidly, he was able to hasten the eruptions in the same manner as the Strokkur Geyser, in Iceland (see p. 218), is made to explode by stopping its mouth with clods of earth. This beautiful illustration of Bunsen's theory 'proves experimentally,' says Dr. Tyndall, 'that the Geyser tube itself is the sufficient cause of the eruptions, and we are relieved from the necessity of imagining underground caverns filled with water and steam, which were formerly regarded as necessary to the production of these wonderful phenomena.'*

Expansive power of liquid gases.—Although aqueous vapour or steam forms a principal part of the aëriform fluids which rush out for days, months, or even years continuously from volcanic vents, there are other gases, such as the carbonic, sulphurous, and hydrochlorous acids, which are also present, and sometimes in great volume. The experiments of Faraday and others have shown that all these gases may be condensed into liquids by pressure. At temperatures of from 30° to 50° Fahr. the pressure required for this purpose varies from 15 to 50 atmospheres; and this amount of pressure we may regard as very insignificant in the operations of nature. A column of Vesuvian lava that would reach from the lip of the crater to the level of the sea, must be equal to about 300 atmospheres; so that, at depths which may be termed moderate in the interior of the crust of the earth, the gases may be condensed into liquids, even at very high temperatures. The method employed to reduce some of these gases to a liquid state is, to confine the materials, from the mutual action of which they are evolved, in tubes hermetically sealed,

* Tyndall: Heat as a Mode of Motion. 1863, p. 126.

so that the accumulated pressure of the vapour, as it rises and expands, may force some part of it to assume the liquid state. A similar process may, and indeed must, frequently take place in subterranean caverns and fissures, or even in the pores and cells of many rocks; by which means, a much greater store of expansive power may be *packed* into a small space than could happen if these vapours had not the property of becoming liquid. For, although the gas occupies much less room in a liquid state, yet it exerts exactly the same pressure upon the sides of the containing cavity as if it remained in the form of vapour.

If a tube, whether of glass or other materials, filled with condensed gas, have its temperature slightly raised, it will often burst; for a slight increment of heat causes the elasticity of the gas to increase in a very high ratio. If a minute hole be bored in the tube, the liquid gas will become instantly aëriform, or, in the language of some writers, it flashes into vapour, and in rushing out often bursts the vessel. We have only to suppose certain rocks, permeated by these liquid gases (as porous strata are sometimes filled with water), to have their temperature raised some hundred degrees, and we obtain a power capable of lifting superincumbent masses of almost any conceivable thickness; while, if the depth at which the gas is confined be great, there is no reason to suppose that any other appearances would be witnessed by the inhabitants at the surface than vibratory movements and rents, since the gases, in making their way through fissured rocks or soft yielding strata, may be cooled and absorbed by water. For water has a strong affinity for several of the gases, and will absorb large quantities, with a very slight increase of volume. In such cases there may be no outburst at the surface, nor any obvious indication of subterranean change. The temperature, perhaps, or volume of springs may be augmented, and their mineral properties altered, but no volcanic explosion may be witnessed. Whether a permanent change of level may be expected to occur as a consequence or accompaniment of such generation and heating of gases in the interior of the earth's crust, will be considered in the sequel.

The volcano of Cotopaxi has been known to throw out, to

the distance of 8 or 9 miles, a mass of rock about 100 cubic yards in volume, and there is no difficulty in understanding how the most solid substances which oppose the upward passage of the exploding gases may be reduced to small fragments, or even to dust, such as we see hurled to the height of many miles into the air by the volcano. In such cases we may suppose a continuous column of liquid lava mixed with *red-hot* or *white-hot water* (for water may exist in that state, as Professor Bunsen reminds us, under pressure), and this column may have a temperature regularly increasing downwards. A disturbance of equilibrium may first bring on an eruption near the surface, by the expansion and conversion into gas of entangled water and other constituents of what we call lava, so as to occasion a diminution of pressure. More steam would then be liberated, carrying up with it jets of melted rock, which being hurled up into the air may fall in showers of ashes on the surrounding country, and at length, by the arrival of lava and water more and more heated at the orifice of the duct or the crater of the volcano, expansive power may be acquired sufficient to expel a massive current of lava. After the eruption has ceased, a period of tranquillity succeeds, during which fresh accessions of heat are communicated from below, and additional masses of rock fused by degrees. At length the conditions required for a new outburst are obtained, and another cycle of similar changes is renewed.

Mr. Scrope suggested, so long ago as 1825,* that liquid lava owed its mobility not so much to simple heat as to the interstitial water contained in the crystalline or semicrystalline matter of the lava, and that the crystals observable in lava, after cooling and hardening, existed there in a more or less complete form previously to emission. This theory, founded on the texture of the lava observed by Mr. Scrope from the eruption of Vesuvius in 1822, although much questioned, and even ridiculed, at the time, has now been accepted by a large number of geologists, and has derived much support from Scheerer's analysis of granite, by which he has proved that water is combined

* Volcanos, 1st ed., p. 22.

chemically with the crystalline matter of that rock in proportions sometimes amounting even to ten per cent.; and also that the different component minerals of this and some other plutonic rocks have become solid one after the other.

Access of water to volcanic foci.—In former editions, I suggested that if the accumulation of heat be granted as successively developed in different parts of the earth's shell, we may readily conceive that the waters of lakes and seas might gain access to the fluid lava during earthquakes, large bodies of water being occasionally engulphed, and then, when the sides of the fissures closed again with violence (see page 125), the steam generated by contact of the water with the heated subterranean fluid might not escape by the same rents, but might rush out with lava from some distinct and perhaps habitual volcanic openings.

Mr. Scrope, in the preface to the last edition of his 'Volcanos' (1871), has objected that the opening of rents by earthquakes and the possible access thereby obtained by bodies of salt or fresh water to subterranean masses of lava would be the effect rather than the cause of volcanic action. I admit there is much force in this argument, for I never considered such sudden contact of water to be the primary cause of the volcano. But, nevertheless, I still think that there may be an intimate connection between an abundance of active volcanic vents and the proximity of seas and lakes. When a combination of heat and compressed gases, such as we have above assumed (p. 224), has given rise to earthquakes, and rent and dislocated the superficial crust, the occasional engulphment of overlying bodies of salt and fresh water may greatly add to the violence and frequency of the explosions.

The experiments and observations of the most eminent chemists have gradually removed, one after another, the objections which were first offered to the doctrine that the salt water of the sea plays a leading part in most volcanic eruptions. Sir H. Davy observed that the fumes which escaped from the Vesuvian lava deposited common salt.*
M. Gay-Lussac, although he avowed his opinion that the decomposition of water contributed largely to volcanic action,

* Davy, Phil. Trans. 1828, p. 244.

called attention, nevertheless, to the supposed fact, that hydrogen had not been detected in a separate form among the gaseous products of volcanos; nor could it, he said, be present; for, in that case, it would be seen inflamed in the air by the red-hot stones thrown out during an eruption.* But M. Abich remarked, on the other hand, 'that although it be true that vapour illuminated by incandescent lava has often been mistaken for flame,' yet he had clearly detected the flame of hydrogen in the eruption of Vesuvius in 1834.†

In the memoir above alluded to, M. Gay-Lussac expressed doubt as to the presence of sulphurous acid; but the abundant disengagement of this gas during eruptions has been since ascertained: and thus all difficulty in regard to the general absence of hydrogen in an inflammable state is removed; for, as Dr. Daubeny suggests, the hydrogen of decomposed water may unite with sulphur to form sulphuretted hydrogen gas, and this gas will then be mingled with the sulphurous acid as it rises to the crater. It is shown by experiment, that these gases mutually decompose each other when mixed where steam is present; the hydrogen of the one immediately uniting with the oxygen of the other to form water, while the excess of sulphurous acid alone escapes into the atmosphere. Sulphur is at the same time precipitated.

This explanation is sufficient; but it may also be observed that the flame of hydrogen would rarely be visible during an eruption; as that gas, when inflamed in a pure state, burns with a very faint blue flame, which even in the night could hardly be perceptible by the side of red-hot and incandescent cinders. Its immediate combination with oxygen to form water when inflamed in the atmosphere, might also account for its not appearing in a separate form.

The observations of Bunsen in Iceland in 1844, of St. Claire Deville on Vesuvius in 1855 and 1861, and of Fouqué on Santorin in 1866, have proved that there is an abundant escape of hydrogen, both in a free state and in combination with other substances, during eruptions; and the two last-

* Ann. de Chim. et de Phys. tom. xxii.

† Phénom. Géol. &c. p. 3.

mentioned chemists have succeeded in demonstrating the perfect accordance of the chemical composition of the products of volcanic eruptions, both gaseous and solid, with the doctrine that salt water has been largely present in the volcanic foci. It had been asked why then are there no salts of magnesia in volcanic fumeroles? They reply that these salts are readily decomposable by hot steam, and that when water and heat are present they produce hydrochloric acid and magnesia. That acid is found in the vapours which are disengaged from red-hot lava, and the magnesia which is not volatile is left behind in the lava itself, constituting one of its most important elements.* In like manner, the last-mentioned French chemists have shown that common salt can be resolved into its elements by hot steam alone, which Gay-Lussac had thought impossible.

M. Fouqué affirms that in the eruption of Etna which he witnessed in 1865, the gaseous emanations agreed in kind with those which we might have looked for if large bodies of sea-water had gained access to reservoirs of subterranean lava, and if they had been decomposed and expelled with the lava; and more than this, he calculated that the quantity of aqueous vapour was relatively to other gases in due proportion—that there was a daily emission from the several vents which were open on Etna, of no less than 22,000 cubic metres of aqueous vapour.

The presence of nitrogen among the gases evolved from craters in eruption, and in the waters of thermal springs, has been another subject of enquiry and discussion. Sir H. Davy, in his memoir on the 'Phenomena of Volcanos,' remarks, that there was every reason to suppose in Vesuvius the existence of a descending current of air; and he imagined that subterranean cavities which threw out large volumes of steam during the eruption, might afterwards, in the quiet state of the volcano, become filled with atmospheric air.† The presence of ammoniacal salts in volcanic emanations, and of ammonia (which is in part composed of nitrogen) in

* Fouqué, Rapport sur les Phénomènes Chimiques. Eruption of Etna in 1865, p. 57.

† Phil. Trans. 1828.

lava, favours greatly the notion of air as well as water being deprived of its oxygen in the interior of the earth. Dr. Daubeny suggests that water containing atmospheric air may descend from the surface of the earth to the volcanic foci, and that the same process of combustion by which water is decomposed may deprive such subterranean air of its oxygen. In this manner great quantities of nitrogen may be evolved. The presence of vast numbers of siliceous cases of infusoria in the tuff covering Pompeii, and composed of matter ejected from Vesuvius, has already been alluded to. (Vol. I. p. 645.) They prove that water and mud have penetrated downwards from the surface into rents and caverns in the interior, and have then been thrown out again during volcanic eruptions.

Chemical action.—When Sir H. Davy first discovered the metallic bases of the earths and alkalies, he threw out the idea that stores of those metals might abound in an unoxidized state in the subterranean regions to which water must occasionally penetrate. Whenever this happened, gaseous matter would be set free, the metals would combine with the oxygen of the water, and sufficient heat might be evolved to melt the surrounding rocks. This hypothesis was at first very favourably received both by the chemist and the geologist: for silica, alumina, lime, soda, and oxide of iron—substances of which lavas are principally composed—would all result from the contact of the elements above alluded to with water. But when Davy failed to detect, during an eruption of Vesuvius, any hydrogen among the gaseous products evolved from the crater, he was disposed to renounce or to attach but little importance to his theory.

We have seen (p. 227) that it is now ascertained that hydrogen is disengaged during eruptions in large quantities, although, according to M. Fouqué, there are always some hydrocarbons mixed with the free hydrogen.* The same chemist remarks, that to explain the disengagement of heat during the last eruption of Etna, we should require a mass of sodium of at least 7,000,000 cubic metres, and therefore

* Fouqué, Rapport sur les Phénomènes Chimiques de l'Éruption de l'Etna en 1865, p. 80.

the quantity of alkaline metals beneath all the active volcanos, which have given rise in each to a long series of eruptions, would be incredibly great. M. Fouqué is satisfied with the hypothesis of a subterranean sheet of fluid lava, to which water occasionally may gain access, central heat being invoked as the power by which the lower parts of the earth's crust are retained in a melted state, and no explanation being attempted by him of the shifting of the volcanic force from one part of the earth's envelope to another.

What we have now said of the manner in which aqueous and other gases may be expected to operate mechanically and chemically on the crust of the earth, whenever water and various acids, stored up in caverns and fissures at great depths, have their temperatures raised, must satisfy the reader that it is only necessary, in order to explain the action of volcanos, to discover some cause which is capable of bringing about such a concentration of heat as may melt, one after the other, certain portions of the solid crust so as to form seas, lakes, or oceans of subterranean lava. This being granted, the greater part of the crust at any given time will contain at various depths sheets of such lava slowly parting with their heat, some semi-fluid, others more or less viscous, and others beginning to consolidate or crystallise. The general state, therefore, of the exterior of the planet would be that of a mass once heated, and which has been gradually cooling; but in certain spots, namely, the regions of active volcanos, regions very limited and exceptional as regards the whole surface, the heat will be sustained near the surface, and will occasionally manifest its intensity in the operations of the volcano and the earthquake.

Mr. Scrope remarks that the absence of volcanic vents in the interior of continents 'would result from the generally admitted fact that the continental tracts have been elevated above the sea-level by internal expansions of deeply-seated matter which could not force its way outwards; or where, in the words of Mr. Mallet, uncompleted efforts to establish a volcano have occurred.'* He considers that there is no proof of any general fluidity of the central nucleus, and that we

* Volcanos: Preface, p. 8. 1872.

cannot safely speculate on the existence in the crust of the globe of more than pockets or local seas and lakes of melted matter. Without pretending to explain in what manner the heated steam may generally gain access to such lava, or how in the course of geological ages it has shifted its principal points of concentration, he remarks that the very different powers of conducting heat in the incumbent rocks must in the course of time cause some of these lavas to part with more heat than others, so that the state of the interior cannot remain constantly the same.

Mr. Babbage in 1834, and Sir J. Herschel independently in the same year,* suggested that differences of temperature in the earth's crust analogous to those above mentioned might be brought about by denudation removing large masses of matter from one part of the crust of the globe, and depositing them in some other region, often far distant, on the floor of the ocean. By this transfer the outward escape of heat would be facilitated in one place where the denuded crust had become thinner, and checked in another where the deposition of new matter had added to its thickness, the planes of the subterranean isothermals or surfaces of equal temperature being thus made to vary. During such changes it is suggested by Mr. Scrope that the direction of the internal heat would be altered, and might sometimes flow laterally towards those avenues for its outward escape which are from time to time afforded by volcanic fissures and earthquake disturbances.

That beneath the Andes and other great areas of active volcanos there are reservoirs, at the depth of some miles, of lava in a constant state of fusion, cannot be doubted from what we have already stated (pp. 90 and 202). All the observed phenomena from which the existence of central fluidity has been inferred are reconcilable with the occurrence at certain depths of such masses of lava in the earth's crust as we have admitted to be probable, and which, even if they equalled the Atlantic and Pacific Oceans in volume, may hold a very subordinate place in the solid shell of the planet.

* Proc. Geol. Soc., Vol. II., p. 75 and p. 550.

The connection of earthquakes with a flexible crust overlying such reservoirs of melted rock is quite conceivable.

Flexibility of the earth's crust.—The inhabitants of Stromboli, who are mostly fishermen, are said to make use of that volcano as a weather-glass, the eruptions being comparatively feeble when the sky is serene, but increasing in turbulence during tempestuous weather, so that in winter the island often seems to shake from its foundations. Mr. P. Scrope, after calling attention to these and other analogous facts, first started the idea (as long ago as the year 1825) that the diminished pressure of the atmosphere, the concomitant of stormy weather, may modify the intensity of the volcanic action. He suggests that where liquid lava communicates with the surface, as in the crater of Stromboli, it may rise or fall in the vent on the same principle as mercury in a barometer; because the ebullition or expansive power of the steam contained in the lava would be checked by every increase, and augmented by every diminution of weight. In like manner, if a bed of liquid lava be confined at an immense depth below the surface, its expansive force may be counteracted partly by the weight of the incumbent rocks, and also in part by atmospheric pressure acting contemporaneously on a vast superficial area. In that case, if the upheaving force increase gradually in energy, it will at length be restrained by only the slightest degree of superiority in the antagonist or repressive power, and then the equilibrium may be suddenly destroyed by any cause, such as an ascending draught of air, which is capable of depressing the barometer. In this manner we may account for the remarkable coincidence so frequently observed between the state of the weather and subterranean commotions, although it must be admitted that earthquakes and volcanic eruptions react in their turn upon the atmosphere, so that disturbances of the latter are generally the consequences rather than the forerunners of volcanic disturbances.*

From an elaborate catalogue of the earthquakes experienced in Europe and Syria during the last fifteen centuries, M.

* Scrope on Volcanos, pp 58–60.

Alexis Perrey concludes that the number which happen in the winter season preponderate over those which occur in any one of the other seasons of the year, there being, however, some exceptions to this rule, as in the Pyrenees. Curious and valuable as are these data, M. d'Archiac justly remarked, in commenting upon them, that they are not as yet sufficiently extensive or accordant in different regions, to entitle us to deduce any general conclusions from them respecting the laws of subterranean movements throughout the globe.*

M. Perrey has also, in a later report of earthquakes (1863), inferred, as the result of 10,000 observations on the earthquakes of the first half of the present century, that they occur more frequently and with more violence when the moon is in perigee, or nearest the earth, than at other periods, when that satellite being less near is exerting a minor degree of force, or less strain upon the solid crust of our planet. In like manner he thinks he has detected a relation between the frequency of earthquakes and our winter and summer solstices, the greatest number of shocks occurring in perihelion when the sun is nearest, and the least number in aphelion when it is farthest from the earth.† On this subject Sir John Herschel remarks, 'The action of the sun and moon, though it cannot produce a tide in the solid crust of the earth, tends to do so, and were it fluid would produce it. It does therefore, in point of fact, bring the solid portions of the earth's surface into a state alternately of strain and compression.'‡

Electricity and magnetism considered as sources of volcanic heat.—The popular notion of a central fluid nucleus, on which a thin outer shell is floating, has diverted the speculations of the physicist and natural philosopher from attempting to invent some theory which might explain the continual shifting of the points of the chief development of heat from one part of the shell to another, leaving large portions previously in a state of fusion to cool and consolidate. Soon after the first great discoveries of Oersted in electro-

* d'Archiac, Hist. des Progrès de la Géol. 1847, vol. i. pp. 605–610.

† Alexis Perrey, Propositions sur les Tremblements de Terre, 1863.

‡ Herschel, Familiar Lectures on Scientific Subjects, 1866, p. 45.

magnetism, Ampère suggested that all the phenomena of the magnetic needle might be explained by supposing currents of electricity to circulate constantly in the shell of the globe in directions parallel to the magnetic equator. This theory has acquired additional consistency the farther we have advanced in science; and according to the experiments of Mr. Fox, on the electro-magnetic properties of metalliferous veins, some trace of electric currents seems to have been detected in the interior of the earth.*

Some philosophers ascribe these currents to the chemical action going on in the superficial parts of the globe to which air and water have the readiest access; while others refer them, in part at least, to thermo-electricity excited by the solar rays on the surface of the earth during its rotation; successive parts of the atmosphere, land, and sea being exposed to the influence of the sun, and then cooled again in the night. That this idea is not a mere speculation, is proved by the correspondence of the diurnal variations of the magnet with the apparent motion of the sun; and by the greater amount of variation in summer than in winter, and during the day than in the night.

Recent discoveries of a connection between periodical changes in the spots of the sun and variations in terrestrial magnetism, have suggested the idea that solar magnetism has a powerful influence on the earth's crust. According to Sir John Herschel, the cycle of change, including the periods when the spots are most abundant and large, and those when they are least apparent, occupies rather more than 11 years, so that there are 9 of these cycles in a century. So late as September 1, 1859, when the spots were very large, 'two observers, far apart and unknown to each other, were viewing them with powerful telescopes, when suddenly, at the same moment of time, both saw a strikingly brilliant luminous appearance, like a cloud of light, far brighter than the general surface of the sun, break out in the immediate neighbourhood of one of the spots, and sweep across and beside it. It occupied about five minutes in its passage, and in that time travelled over a space on the sun's surface which could not

* Phil. Trans. 1830, p. 399.

be estimated at less than 35,000 miles. A magnetic storm was in progress at the time. From August 28 to September 4 many indications showed the earth to have been in a perfect convulsion of electro-magnetism.'

At Kew, where there are self-registering magnetic instruments, by which the positions of three magnetic needles are recorded by photography, it was found that all three had made a strongly marked jerk from their former positions at the very moment when the bright light had been seen crossing the solar spot. It would appear that the magnetic influence had reached the earth at the same time with the light.

'By degrees, accounts began to pour in of great Auroras seen on the nights of those days, not only in these latitudes, but at Rome, in the West Indies, on the tropics within 18° of the equator (where they hardly ever appear), nay, what is still more striking, in South America and in Australia, where, at Melbourne, on the night of the 2nd of September, the greatest Aurora ever seen there made its appearance. These Auroras were accompanied by unusually great electro-magnetic disturbances in every part of the world. In many places the telegraphic wires struck work. At Washington and Philadelphia, in America, the telegraph signal-men received severe electric shocks. At a station in Norway the telegraphic apparatus was set fire to; and at Boston, in North America, a flame of fire followed the pen of Bain's electric telegraph, which writes down the message upon chemically prepared paper.'*

The passage of this electro-magnetic force from the sun to our globe may, perhaps, be one of the principal means by which heat lost by radiation into space may be restored to the planet; and we may easily imagine that at successive geological periods, when new mountain chains have been thrown up and old ones have been removed by subsidence or denudation, when even oceans and continents have changed places, the circulation of electro-magnetic currents and the local concentration of heat due to them may affect new parts of the exterior of the planet. It is scarcely possible to exag-

* Herschel, Familiar Lectures on Scientific Subjects, 1866, p. 80.

gerate the amount of action and reaction to which the cause here alluded to may give rise. 'The silent and slow operation of electricity as a chemical agent is more important,' says Davy, 'in the economy of nature than its grand and impressive operation in lightning and thunder. It may be considered, not only as directly producing an infinite variety of changes, but as influencing almost all which take place; it would seem, indeed, that chemical attraction itself is only a peculiar form of the exhibition of electrical attraction.'*

Thermo-electricity may be generated by great inequalities of temperature, arising from a partial distribution of volcanic heat. Wherever, for example, masses of rock occur of great horizontal extent, and of considerable depth, which are at one point in a state of fusion (as beneath some active volcano); at another, red-hot; and at a third, comparatively cold—strong thermo-electric action may be excited, and subterranean electric currents, if once excited, may melt rock or possess the decomposing power of the voltaic pile.

But the difficulties we encounter when we attempt to form a chemical theory of volcanos, are almost insurmountable, in consequence of our inability to test experimentally the mode in which different substances, solid, fluid, or gaseous, would behave under conditions of pressure and temperature wholly different from those experienced at the surface. A simple difference in the amount of heat may cause all the chemical affinities of bodies to be essentially modified. Mercury does not combine with oxygen at ordinary temperatures, but combines with it at its boiling point, and then gives it off again at an incipient red heat. Here we have three different states of chemical affinity within the limits of a few hundred degrees; and who would dare assert, that at this last phase of separation, the chemical action between these two elements ceases definitely and for all higher temperatures? But what is true of mercury and oxygen, is likewise true *mutatis mutandis* for all other elements.

That there should be so much heat and chemical action and reaction, developed in certain parts of the interior of the

* Consolations in Travel, p. 271.

earth, is not so wonderful as the ordinary repose and inertness of the internal mass. When we consider the combustible nature of the elements of the earth, so far as they are known to us—the facility with which their compounds may be decomposed and made to enter into new combinations—the quantity of heat which they evolve during these processes; when we recollect the expansive power of steam, and call to mind the number of explosive and detonating compounds which have been already discovered, we may be allowed to share the astonishment of Pliny, that a single day should pass without a general conflagration:—'Excedit profectò omnia miracula, ullum diem fuisse quo non cuncta conflagrarent.'*

Causes of permanent elevation and subsidence of land.—The position of the fossiliferous and other rocks in the earth's crust has enabled the geologist to infer that some of these rocks have been lifted up to the height of several miles above the level at which they were originally formed in the bed of the ocean, and also that there have been gradual subsidences of rocks to a vast amount below the levels which they once occupied. These great movements have been caused by subterranean or volcanic heat, which has affected different parts of the earth in succession. The existing mountain chains are of different ages, and few of them owe the whole of their present conformation to the movements experienced in a single epoch. The forces, whether in an upward or downward direction, to which they are due, and by which the varying position of continents and oceanic basins has in the course of ages been determined, have evidently shifted their points of chief development from one region to another, like the volcano and the earthquake, and are in fact all the results of the same internal operations, to which heat, electricity, magnetism, and chemical affinity give rise.

Experiments were made in America, by Colonel Totten, to ascertain the ratio according to which some of the stones commonly used in architecture expand with given increments of heat.† It was found impossible, in a country where the

* Hist. Mundi, lib. ii. c. 107.

† Silliman's American Journ. vol. xxii. p. 136. The application of these results to the theory of earthquakes was first suggested to me by Mr. Babbage.

annual variation of temperature was more than 90° Fahr., to make a coping of stones, 5 feet in length, in which the joints should fit so tightly as not to admit water between the stone and the cement; the annual contraction and expansion of the stones causing, at the junctions, small crevices, the width of which varied with the nature of the rock. It was ascertained that fine-grained granite expanded with 1° Fahr. at the rate of ·000004825; white crystalline marble ·000005668; and red sandstone ·000009532, or about twice as much as granite.

Now, according to this law of expansion, a mass of sandstone, a mile in thickness, which should have its temperature raised 200° Fahr. would lift a superimposed layer of rock to the height of 10 feet above its former level. But, suppose a part of the earth's crust, 50 miles in thickness and equally expansible, to have its temperature raised 600° or 800°, this might produce an elevation of between 1,000 and 1,500 feet. The cooling of the same mass might afterwards cause the overlying rocks to sink down again and resume their original position. By such agency we might explain the gradual rise of part of Scandinavia or the subsidence of Greenland.

It is also possible that as the clay in Wedgwood's pyrometer contracts, by giving off its water, and then, by incipient vitrification; so, large masses of argillaceous strata in the earth's interior may shrink, when subjected to heat and chemical changes, and allow the incumbent rocks to subside gradually.

Moreover, if we suppose that lava cooling slowly at great depths may be converted into various granitic rocks, we obtain another source of depression; for, according to the experiments of Deville and the calculations of Bischoff, the contraction of granite when passing from a melted or plastic to a solid and crystalline state must be more than 10 per cent.*—though Mr. David Forbes is of opinion from experiments made by him on a larger scale that this percentage is too high.†

Dr. Bischoff has also remarked, that when the silicates

* Bulletin de la Soc. Géol. 2nd series, vol. iv. p. 1312.

† Chemical News, Oct. 23, 1868.

which enter so largely into the composition of the oldest rocks —gneiss, mica-schist, clay-slate, and others—are percolated by carbonic acid gas, which is of almost universal occurrence at great depths, they must be continually decomposed. When that happens, the carbonates formed by the new combinations thence arising must often augment the volume of the altered rocks. This increase of bulk, he says, must sometimes give rise to a mechanical force of expansion capable of uplifting the incumbent crust of the earth, and the same force may act laterally, so as to compress, dislocate, and tilt the strata on each side of a mass in which the new chemical changes are developed. The same eminent German chemist has attempted to calculate the exact amount of distension to which the new mineral products thus formed may give rise by adding to the volume of the rocks.

If once some parts of the earth's crust are shattered, as in regions of earthquakes, and reservoirs of melted stone and heated vapours have acquired force enough to uplift the incumbent mass, we may easily conceive how the country may remain permanently upheaved. For in some places the fractured rocks below may have assumed an arched form, or lava may have been driven into fissures, in which it may consolidate, and afford an enduring support to the foundations of the newly raised strata.

The sudden subsidence of limited areas of land may be occasioned by subterranean caverns giving way, when gases are condensed, or when they escape through newly-formed crevices. The subtraction, moreover, of matter from certain parts of the interior, by the flowing of lava, and of mineral springs, must, in the course of ages, cause vacuities below, so that the undermined surface may at length fall in or be slowly depressed. In this manner we may, perhaps, explain the geographical connection which seems to exist between areas of elevation and of subsidence, a deep sea being often contiguous to elevated land.

Balance of dry land, how preserved.—It will appear, from the historical details above given, that the force of subterranean movement, whether intermittent or continuous, whether with or without disturbance, does not operate at random, but is

developed in certain regions only; and although the alterations produced during the time required for the occurrence of a few volcanic eruptions may be inconsiderable, we can hardly doubt that, during the ages necessary for the formation of large volcanic cones, composed of thousands of lava currents, shoals might be converted into lofty mountains, and low lands into deep seas.

In a former chapter (Vol. I. p. 321), I have stated that aqueous and igneous agents may be regarded as antagonist forces; the aqueous labouring incessantly to reduce the inequalities of the earth's surface to a level, while the igneous are equally active in renewing the unevenness of the surface. By some geologists it has been thought that the levelling power of running water was opposed rather to the *elevating* force of earthquakes than to their action generally. This opinion is, however, untenable; for the sinking down of the bed of the ocean is one of the means by which the gradual submersion of land is prevented. The depth of the sea cannot be increased at any one point without a universal fall of the waters, nor can any partial deposition of sediment occur without the displacement of a quantity of water of equal volume, which will raise the sea, though in an imperceptible degree, even to the antipodes. The preservation, therefore, of the dry land may sometimes be effected by the subsidence of part of the earth's crust (that part, namely, which is covered by the ocean), and in like manner an upheaving movement must often tend to destroy land; for if it render the bed of the sea more shallow, it will displace a certain quantity of water, and thus tend to submerge low tracts.

If the dimensions of the planet have remained uniform during the period which we contemplate in geology, it would be necessary to suppose that the amount of depression caused by subterranean heat must exceed that of elevation, otherwise there would not be a perpetual restoration of those inequalities of the earth's surface which the levelling power of water tends to efface. It would be otherwise if the action of volcanos and mineral springs were suspended; for then the forcing outwards of the earth's envelope ought to be no more than equal to its sinking in.

To understand this proposition more clearly, it must be borne in mind, that the deposits of rivers and currents probably add as much to the height of submerged lands which are rising, as they take from those which have risen. Suppose a large river to bring down sediment to a part of the ocean 2,000 feet deep, and that the depth of this part is gradually reduced by the accumulation of sediment till only a shoal remains, covered by water at high tides; if now an upheaving force should uplift this shoal to the height of 2,000 feet, the result would be a mountain 2,000 feet high. But had the movement raised the same part of the bottom of the sea before the sediment of the river had filled it up; then, instead of changing a shoal into a mountain 2,000 feet high, it would only have converted a deep sea into a shoal.

It appears, then, that the operation of the volcanic or subterranean forces is often such as to cause the levelling power of water to counteract itself; and, although the idea may appear paradoxical, we may be sure, wherever we find hills and mountains composed of stratified deposits, that such inequalities of the surface would have had no existence if water, at some former period, had not been labouring to reduce the earth's surface to one level.

But, besides the transfer of matter by running water from the continents to the ocean, there is a constant transportation from below upwards, by mineral springs and volcanic vents. As mountain masses are, in the course of ages, created by the pouring forth of successive streams of lava, so stratified rocks of great extent originate from the deposition of carbonate of lime, and other mineral ingredients, with which springs are impregnated. The surface of the land, and portions of the bottom of the sea, being thus raised, the external accessions due to these operations would cause the dimensions of the planet to enlarge continually, if the amount of depression of the earth's crust were no more than equal to the elevation. In order, therefore, that the mean diameter of the earth should remain uniform, and the unevenness of the surface be preserved, it is necessary that the amount of subsidence should be in excess. And such a predominance of depression is far from improbable, on mechanical prin-

ciples, since every upheaving movement must be expected either to produce caverns in the mass below, or to cause some diminution of its density. Vacuities must, also, arise from the subtraction of the matter poured out from volcanos and mineral springs, or from the contraction of argillaceous masses by subterranean heat; and the foundations having been thus weakened, the earth's crust, shaken and rent by reiterated convulsions, must, in the course of time, fall in.

It seems, therefore, to be rendered probable, by the views above explained, that the constant repair of the land, and the subserviency of our planet to the support of terrestrial as well as aquatic species, are secured by the elevating and depressing power of causes acting in the interior of the earth; which, although so often the source of death and terror to the inhabitants of the globe—visiting in succession every zone, and filling the earth with monuments of ruin and disorder—are nevertheless the agents of a conservative principle above all others essential to the stability of the system.

Recapitulation of Chapters XXXII. and XXXIII.—I will now recapitulate the principal conclusions arrived at in this and in the preceding chapter.

1. The primary causes of the volcano and the earthquake are to a great extent the same, and connected with the development of heat and chemical action at various depths in the interior of the globe.

2. Volcanic heat has been supposed by many to be the result of the high temperature which belonged to the whole planet when it was in a state of igneous fusion, a temperature which they suppose to have been always diminishing and still to continue to diminish by radiation into space, but recent enquiries have suggested that the apparent loss of heat may arise from the successive local development of volcanic action.

3. The spheroidal figure of the earth does not of necessity imply a universal and simultaneous fluidity, in the beginning; for whatever may have been the original shape of our planet, the statical figure must have been assumed, if sufficient time be allowed, by the gradual operation of the centrifugal force, acting on yielding materials brought successively within its action by aqueous and igneous causes.

4. The late Mr. Hopkins inferred that the precessional motion of the earth could not be such as it now is, unless the solid crust was at least from 800 to 1,000 miles thick; but the precessional movement is consistent with the supposition of a much greater thickness, and even with the general solidity of the entire globe, provided that lakes or oceans of melted matter, which may be distributed through it, are so enclosed as to move with the solid portion.

5. The heat in mines and Artesian wells increases as we descend, but not in a uniform ratio, in different regions. If the heat were continued downwards at the same rate, it would imply such an elevation of temperature in the central nucleus as must instantly fuse the crust.

6. The hypothesis of a central fluid and of a thin solid shell resting or floating upon it, is inconsistent with the absence of internal tides, such as would make the lava ebb and flow in volcanic craters during eruptions.

7. The hypothesis of a change in the axis of rotation of a supposed solid envelope, made to slide over an internal fluid nucleus in consequence of the transfer of sediment from higher to lower, or from lower to higher, latitudes, is untenable, because the excess of matter displaced and carried in one direction would be extremely slight, and the oblato-spheroidal figure of the earth would render such freedom of motion impossible.

8. Assuming that there were good astronomical grounds for inferring the original fluidity of the planet, such pristine fluidity need not affect the question of volcanic heat, for the volcanic action of successive periods belongs to a state of the globe lông posterior to its origin, and implies the melting of different parts of the solid crust one after the other.

9. The quantity of lava, fluid at any one time in the earth's crust, although it may be of importance in reference to superficial changes, such as the formation of mountain chains, or lines of volcanic vents, or regions of earthquakes, may still be quite insignificant in relation to the size of an external shell having a thickness of 50 miles.

10. The supposed greater energy of the volcanic forces in the remoter periods is by no means borne out by geological

observations on the quantity of lava produced by single eruptions in those several periods.

11. The old notion that the crystalline rocks, whether stratified or unstratified, such as granite and gneiss, were produced in the lower parts of the earth's crust at the expense of a central nucleus slowly cooling from a state of fusion by heat, has had to be given up, now that granite is found to be of all ages, and now that we know the metamorphic rocks to be altered sedimentary deposits implying the denudation of a previously solidified crust.

12. The powerful agency of steam or aqueous vapour in volcanic eruptions leads us to compare its power of propelling lava to the surface with that which it exerts in driving up water in the pipe of an Icelandic Geyser. Various gases also, rendered liquid by pressure at great depths, may aid in causing volcanic outbursts, and in fissuring and convulsing the rocks during earthquakes.

13. The latest chemical observations on the products of recent eruptions, favour the doctrine that large bodies of salt water gain access to the volcanic foci. Although this may not be the primary cause of volcanic eruptions, which are probably due to the aqueous vapour intimately mixed with molten rock, yet when once the crust has been shattered, and a communication been opened with the surface, the force and frequency of eruptions may depend in some measure on the proximity of large overlying bodies of water.

14. The flexibility of certain parts of the earth's crust, as deduced from observations on earthquakes, may imply the continuous existence of vast reservoirs of melted matter beneath the surface, but such nevertheless as might hold a very subordinate place in the earth's crust.

15. The existence of electrical currents in the earth's crust, and the changes in direction which they may undergo after great geological revolutions in the position of mountain chains and of land and sea, the connection also of solar and terrestrial magnetism, and of this last with electricity and chemical action, may help us to conceive such a cycle of change as may restore to the planet the heat supposed to be lost by radiation into space.

16. The permanent elevation and subsidence of land now observed, and which have been going on throughout past geological ages, may be connected with the expansion and contraction of parts of the solid crust, some of which have been cooling from time to time, while others have been gaining fresh accessions of heat.

17. In the preservation of the average proportion of land and sea, the igneous agents exert a conservative power, restoring the unevenness of the surface, which the levelling power of water in motion would tend to destroy. If the diameter of the planet remains always the same,* the downward movements of the crust must be somewhat in excess, to counterbalance the effect of volcanos and mineral springs, which are always bringing up materials from the interior of the earth and pouring them out at the surface, so as to raise its level. Subterranean movements, therefore, however destructive they may be during great earthquakes, are essential to the well-being of the habitable surface, and even to the very existence of terrestrial species.

* See vol. i. p. 304.

BOOK III.

CHANGES OF THE ORGANIC WORLD NOW IN PROGRESS.

CHAPTER XXXIV.

LAMARCK ON THE TRANSMUTATION OF SPECIES.

DIVISION OF THE SUBJECT—EXAMINATION OF THE QUESTION, WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE?—IMPORTANCE OF THIS QUESTION IN GEOLOGY—SKETCH OF LAMARCK'S ARGUMENTS IN FAVOUR OF THE TRANSMUTATION OF SPECIES, AND HIS CONJECTURES RESPECTING THE ORIGIN OF EXISTING ANIMALS AND PLANTS—HIS THEORY OF THE TRANSFORMATION OF THE ORANG-OUTANG INTO THE HUMAN SPECIES.

HITHERTO we have been occupied, from Chap. XV. to Chap. XXXIII., with the consideration of the changes brought about on the earth's surface, within the period of human observation, by inorganic agents; such, for example, as rivers, marine currents, volcanos, and earthquakes. But there is another class of phenomena relating to the organic world, which have an equal claim on our attention, if we desire to obtain possession of all the preparatory knowledge respecting the existing course of nature, which may be available in the interpretation of geological monuments. It appeared from our preliminary sketch of the progress of the science, that the most lively interest was excited among its earlier cultivators, by the discovery of the remains of animals and plants in the interior of mountains frequently remote from the sea. Much controversy arose respecting the nature of these remains, the causes which may have brought them into so singular a position, and the want of a specific agreement between them and known animals and plants. To qualify ourselves to form just views on these curious questions, we must first study the present condition of the animate creation on the globe.

This branch of our enquiry naturally divides itself into two parts:—

First, we may consider the various meanings which have been attached to the term 'species,' and the question which has been raised whether each species has remained from its origin the same, only varying within certain fixed and defined limits, or whether a species may be indefinitely modified in the course of a long series of generations. This will lead us to examine into the dependence of each species of animal and plant on certain fluctuating and temporary conditions in the animate and inanimate world, and the consequent extinction of species one after the other, and the manner in which the places left vacant may be supplied by new animals and plants better fitted for the new conditions.

Secondly, we may consider the processes by which some individuals of certain species may occasionally become fossil, or be preserved in such a manner as to form part of the solid framework of the earth's crust, so that they may serve in after ages as monuments of the state of the living world at the time when they became fossil.

Before we can advance a step in our enquiry, we must endeavour to make up our minds as to the meaning which we attach to the term 'species.' This is even more necessary in geology than in the ordinary studies of the naturalist; for they who contend for the indefinite modifiability of species, admit, nevertheless, that a botanist or zoologist may reason as if the specific character were constant, because they confine their observations to a brief period of time. Just as the astronomer, in constructing his maps of the heavens, may proceed century after century as if the apparent places of the fixed stars remained absolutely the same, and as if no alteration were brought about by the proper motion of the sun; so, it is said, in the organic world, the stability of a species may be taken as absolute, if we do not extend our views beyond the narrow period of human history; but let a sufficient number of centuries elapse, to allow of important revolutions in climate, physical geography, and other circumstances, and the characters, say they, of the descendants of common parents may deviate indefinitely from their original type.

Now, if these doctrines be tenable, we are at once presented with a principle of incessant change in the organic world; and no degree of dissimilarity in the plants and animals which may formerly have existed, and are found fossil, would entitle us to conclude that they may not have been the prototypes and progenitors of the species now living. Accordingly MM. Lamarck and Geoffroy St. Hilaire declared their opinion in the beginning of the present century that there had been an uninterrupted succession in the animal kingdom, effected by means of generation, from the earliest ages of the world up to the present day, and that the ancient animals whose remains have been preserved in the strata, however different, may nevertheless have been the ancestors of those now in being. In order to explain the facts and reasoning by which this theory was originally supported, I cannot do better than offer the reader a rapid sketch of the proofs which were regarded by Lamarck as confirmatory of his views, shared as they were to a great extent by his contemporary, Geoffroy St. Hilaire.*

Lamarck's arguments in favour of the transmutation of species.—The name of 'species,' observes Lamarck, has been usually applied to 'every collection of similar individuals produced by other individuals like themselves.'† The defini-

* I have reprinted in this chapter, word for word, my abstract of Lamarck's doctrine of transmutation as drawn up by me in 1832 in the first edition of the 'Principles of Geology,' vol. ii. chap. i. I have thought it right to do this in justice to Lamarck, in order to show how nearly the opinions taught by him at the commencement of this century resembled those now in vogue amongst a large body of naturalists respecting the indefinite variability of species, and the progressive development in past time of the organic world. The reader must bear in mind that when I made this analysis of the 'Philosophie Zoologique,' in 1832, I was altogether opposed to the doctrine that the animals and plants now living were the lineal descendants of distinct species only known to us in a fossil state; and it will be seen, by reference to p. 274, that, so far from exaggerating, I did not do justice to the arguments originally adduced by Lamarck and Geoffroy St. Hilaire, especially those founded on the occurrence of rudimentary organs. There is, therefore, no room for suspicion that my account of the Lamarckian hypothesis, written by me thirty-five years ago, derived any colouring from my own views tending to bring it more into harmony with the theory since promulgated by Darwin. The law of natural selection, by which the last-mentioned great naturalist has thrown so much new light on the origin of species, will be explained in the next and succeeding chapters.

† Phil. Zool. tom. i. p. 54. 1809.

tion, he admits, is correct; because every living individual bears a very near resemblance to those from which it springs. But this is not all which is usually implied by the term 'species;' for the majority of naturalists agree with Linnæus in supposing that all the individuals propagated from one stock have certain distinguishing characters in common, which will never vary, and which have remained the same since the creation of each species. Lamarck proposed, therefore, to amplify the received definition in the following manner. 'A species consists of a collection of individuals resembling each other, and reproducing their like by generation, so long as the surrounding conditions do not alter to such an extent as to cause their habits, characters, and forms to vary.'

In order to show the grounds for this limitation of the word 'species,' Lamarck entered upon the following line of argument:—The more we advance in the knowledge of the different organised bodies which cover the surface of the globe, the more our embarrassment increases to determine what ought to be regarded as a species, and still more how to limit and distinguish genera. In proportion as our collections are enriched, we see almost every void filled up, and all our lines of separation effaced; we are reduced to arbitrary determinations, and are sometimes fain to seize upon the slight differences of mere varieties, in order to form characters for what we choose to call a species; and sometimes we are induced to pronounce individuals but slightly differing and which others regard as true species, to be varieties.

The greater the abundance of natural objects assembled together, the more do we discover proofs that everything passes by insensible shades into something else; that even the more remarkable differences are evanescent, and that nature has, for the most part, left us nothing at our disposal for establishing distinctions, save trifling, and, in some respects, puerile peculiarities.

We find that many genera amongst animals and plants are of such an extent, in consequence of the number of species referred to them, that the study and determination

of these last has become almost impracticable. When the species are arranged in a series, and placed near to each other, with due regard to their natural affinities, they each differ in so minute a degree from those next adjoining, that they almost melt into each other, and are in a manner confounded together. If we see isolated species, we may presume the absence of some more closely connected, and which have not yet been discovered. Already are there genera, and even entire orders—nay, whole classes—which present an approximation to the state of things here indicated.

If, when species have been thus placed in a regular series, we select one, and then, making a leap over several intermediate ones, we take a second, at some distance from the first, these two will, on comparison, be seen to be very dissimilar; and it is in this manner that every naturalist begins to study the objects which are at his own door. He then finds it an easy task to establish generic and specific distinctions; and it is only when his experience is enlarged, and when he has made himself master of the intermediate links, that his difficulties and ambiguities begin. But while we are thus compelled to resort to trifling and minute characters in our attempt to separate species, we find a striking disparity between individuals which we know to have descended from a common stock; and these newly acquired peculiarities are regularly transmitted from one generation to another, constituting what are called *races*.

From a great number of facts, continues the author, we learn that in proportion as the individuals of one of our species change their situation, climate, and manner of living, they change also, by little and little, the consistence and proportions of their parts, their form, their faculties, and even their organisation, in such a manner that everything in them comes at last to participate in the mutations to which they have been exposed. Even in the same climate, a great difference of situation and exposure causes individuals to vary; but if these individuals continue to live and to be reproduced under the same difference of circumstances, distinctions are brought about in them which become in some degree essential to their existence. In a word, at the

end of many successive generations, these individuals, which originally belonged to another species, are transformed into a new and distinct species.*

Thus, for example, if the seeds of a grass, or any other plant which grows naturally in a moist meadow, be accidentally transported, first to the slope of some neighbouring hill, where the soil, although at a greater elevation, is damp enough to allow the plant to live; and if, after having lived there, and having been several times regenerated, it reaches by degrees the drier and almost arid soil of a mountain declivity, it will then, if it succeeds in growing, and perpetuates itself for a series of generations, be so changed that botanists who meet with it will regard it as a peculiar species.* The unfavourable climate in this case, deficiency of nourishment, exposure to the winds, and other causes, give rise to a stunted and dwarfish race, with some organ more developed than others, and having proportions often quite peculiar.

What nature brings about in a great lapse of time, we occasion suddenly by changing the circumstances in which a species has been accustomed to live. All are aware that vegetables taken from their birthplace, and cultivated in gardens, undergo changes which render them no longer recognisable as the same plants. Many which were naturally hairy become smooth, or nearly so; a great number of such as were creepers and trailed along the ground, rear their stalks and grow erect. Others lose their thorns or asperities; others, again, from the ligneous condition which characterised their stem in the hot climates, where they were indigenous, pass to the herbaceous; and, among them, some which were perennials become mere annuals. So well do botanists know the effects of such changes of circumstances, that they are averse to describe species from garden specimens, unless they are sure that they have been cultivated for a very short period.

'Is not the cultivated wheat' (*Triticum sativum*), asks Lamarck, 'a vegetable brought by man into the state in which we now see it? Let anyone tell me in what country

* Phil. Zool. tom. i. p. 63.

a similar plant grows wild, unless where it has escaped from cultivated fields? Where do we find in nature our cabbages, lettuces, and other culinary vegetables, in the state in which they appear in our gardens? Is it not the same in regard to a great number of animals which domesticity has changed or considerably modified?'* Our domestic fowls and pigeons are unlike any wild birds. Our domestic ducks and geese have lost the faculty of raising themselves into the higher regions of the air, and crossing extensive countries in their flight, like the wild ducks and wild geese from which they were originally derived. A bird which we breed in a cage cannot, when restored to liberty, fly like others of the same species which have been always free. This small alteration of circumstances, however, has only diminished the power of flight, without modifying the form of any part of the wings. But when individuals of the same race are retained in captivity during a considerable length of time, the form even of their parts is gradually made to differ, especially if climate, nourishment, and other circumstances be also altered.

The numerous races of dogs which we have produced by domesticity are nowhere to be found in a wild state. In nature we should seek in vain for mastiffs, harriers, spaniels, greyhounds, and other races, between which the differences are sometimes so great that they would be readily admitted as specific between wild animals; 'yet all these have sprung originally from a single race, at first approaching very near to a wolf, if, indeed, the wolf be not the true type which at some period or other was domesticated by man.'

Although important changes in the nature of the places which they inhabit modify the organisation of animals as well as vegetables; yet the former, says Lamarck, require more time to complete a considerable degree of transmutation; and, consequently, we are less sensible of such occurrences. Next to a diversity of the medium in which animals or plants may live, the circumstances which have most influence in modifying their organs are differences in exposure, climate, the nature of the soil, and other local

* Phil. Zool. tom. i. p. 227.

particulars. These circumstances are as varied as are the characters of the species, and, like them, pass by insensible shades into each other, there being every intermediate gradation between the opposite extremes. But each locality remains for a very long time the same, and is altered so slowly that we can only become conscious of the reality of the change by consulting geological monuments, by which we learn that the order of things which now reigns in each place has not always prevailed, and by inference anticipate that it will not always continue the same.*

Every considerable alteration in the local circumstances in which each race of animals exists causes a change in their wants, and these new wants excite them to new actions and habits. These actions require the more frequent employment of some parts before but slightly exercised, and then greater development follows as a consequence of their more frequent use. Other organs no longer in use are impoverished and diminished in size, nay, are sometimes entirely annihilated, while in their place new parts are insensibly produced for the discharge of new functions.†

I must here interrupt the author's argument, by observing, that no positive fact is cited to exemplify the substitution of some *entirely new* sense, faculty, or organ, in the room of some other suppressed as useless. All the instances adduced go only to prove that the dimensions and strength of members and the perfection of certain attributes may, in a long succession of generations, be lessened and enfeebled by disuse; or, on the contrary, be matured and augmented by active exertion; just as we know that the power of scent is feeble in the greyhound, while its swiftness of pace and its acuteness of sight are remarkable—that the harrier and stag-hound, on the contrary, are comparatively slow in their movements, but excel in the sense of smelling.

It was necessary to point out to the reader this important chasm in the chain of evidence, because he might otherwise imagine that I had merely omitted the illustrations for the sake of brevity; but the plain truth is, that there were no

* Phil. Zool. tom. i. p. 232.

† Ibid. p. 234.

examples to be found; and when Lamarck talked 'of the efforts of internal sentiment,' 'the influence of subtle fluids,' and 'acts of organisation,' as causes whereby animals and plants acquire *new organs*, he substituted names for things; and resorted to fictions almost as ideal as the 'plastic virtue' of some geologists of the middle ages.

It is evident that, if some well authenticated facts could have been adduced to establish one complete step in the process of transformation, such as the appearance, in individuals descending from a common stock, of a sense or organ entirely new, and a complete disappearance of some other enjoyed by their progenitors, time alone might then be supposed sufficient to bring about any amount of metamorphosis.*

But to proceed with the system: it being taken for granted, as an undoubted fact, that a change of external circumstances may cause one organ to become entirely obsolete and a new one to be developed, such as never before belonged to the species, the following proposition is announced, which, however startling it may seem, is logically deduced from the assumed premises. It is not the organs, or, in other words, the nature and form of the parts of the body of an animal, which have given rise to its habits and its particular faculties; but, on the contrary, its habits, its manner of living, and those of its progenitors, have in the course of time determined the form of its body, the number and condition of its organs—in short, the faculties which it enjoys. Thus otters, beavers, waterfowl, turtles, and frogs, were not made web-footed in order that they might swim; but their wants having attracted them to the water in search of prey, they stretched out the toes of their feet to strike the water and move rapidly along its surface. By the repeated stretching of their toes, the skin which united them at the base acquired a habit of extension, until, in the course of time, the

* Note, 1872. This perhaps could not be done by Lamarck, nor by any of his successors, on account of the slowness of such changes; but it would have answered the same purpose if any cause or law had been indicated capable of accumulating slight changes continually in one direction and for a special end; and it is for want of this that the theory of Lamarck fell so far short of that of Mr. Darwin, presently to be described.

broad membranes which now connect their extremities were formed.

In like manner, the antelope and the gazelle were not endowed with light agile forms, in order that they might escape by flight from carnivorous animals; but, having been exposed to the danger of being devoured by lions, tigers, and other beasts of prey, they were compelled to exert themselves in running with great celerity; a habit which, in the course of many generations, gave rise to the peculiar slenderness of their legs, and the agility and elegance of their forms.

The giraffe was not gifted with a long flexible neck because it was destined to live in the interior of Africa, where the soil was arid and devoid of herbage; but, being reduced by the nature of that country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its neck became so elongated that it could raise its head to the height of 20 feet above the ground.

Another line of argument was then entered upon, in further corroboration of the instability of species. In order, it was said, that individuals should perpetuate themselves unaltered by generation, those belonging to one species ought never to ally themselves to those of another; but such sexual unions do take place, both among plants and animals; and though the offspring of such irregular connections are usually sterile, yet such is not always the case. Hybrids have sometimes proved prolific, where the disparity between the species was not too great; and by this means alone, says Lamarck, varieties may gradually be created by near alliances, which would become races, and in the course of time would constitute what we term species.*

After explaining his reasons for believing in the soundness of the arguments and inferences above set forth, Lamarck next proceeded to enquire what were the original types of form, organisation, and instinct, from which the diversities of character, as now exhibited by animals and plants, were derived? We know, said he, that individuals which are mere varieties of the same species would, if their pedigree

* Phil. Zool. p. 64.

could be traced back far enough, terminate in a single stock; so, according to the same train of reasoning, the species of a genus, and even the genera of a great family, must have had a common point of departure. What, then, was the single stem from which so many varieties of form have ramified? Were there many of these, or are we to refer the origin of the whole animate creation, as the Egyptian priests did that of the universe, to a single egg?

In the absence of any positive data for framing a theory on so obscure a subject, the following considerations were deemed by Lamarck of importance to guide conjecture.

In the first place, if we examine the whole series of known animals, from one extremity to the other, when they are arranged in the order of their natural relations, we find that we may pass progressively, or at least, with very few interruptions, from beings of more simple to those of a more compound structure; and, in proportion as the complexity of their organisation increases, the number and dignity of their faculties increase also. Among plants, a similar approximation to a graduated scale of being is apparent. Secondly, it appears, from geological observations, that plants and animals of more simple organisation existed on the globe before the appearance of those of more compound structure, and the latter was successively formed at more modern periods; each new race being more fully developed than the most perfect of the preceding era.

Of the truth of the last-mentioned geological theory, Lamarck seems to have been fully persuaded; and he also shows that he was deeply impressed with a belief prevalent amongst the older naturalists, that the primeval ocean invested the whole planet long after it became the habitation of living beings; and thus he was inclined to assert the priority of the types of marine animals to those of the terrestrial, so as to fancy, for example, that the testacea of the ocean existed first, until some of them, by gradual evolution, were *improved* into those inhabiting the land.

These speculative views had already been, in a great degree, anticipated by Demaillet in his Telliamed, and by several other writers who preceded Lamarck; so that the tables were com-

pletely turned on the philosophers of antiquity, with whom it was a received maxim, that created things were always most perfect when they came first from the hands of their Maker; and that there was a tendency to progressive deterioration in sublunary things when left to themselves—

> ——— omnia fatis
> In pejus ruere, ac retrò sublapsa referri.

So deeply was the faith of the ancient schools of philosophy imbued with this doctrine, that, to check this universal proneness to degeneracy, nothing less than the re-intervention of the Deity was thought adequate; and it was held, that thereby the order, excellence, and pristine energy of the moral and physical world had been repeatedly restored.

But when the possibility of the indefinite modification of individuals descending from common parents was once assumed, as also the geological inference respecting the progressive development of organic life, it was natural that the ancient dogma should be rejected, or rather reversed, and that the most simple and imperfect forms and faculties should be conceived to have been the originals whence all others were developed. Accordingly, in conformity to these views, inert matter was supposed to have been first endowed with life; until, in the course of ages, sensation was super-added to mere vitality: sight, hearing, and the other senses were afterwards acquired; then instinct and the mental faculties; until, finally, by virtue of the tendency of things to *progressive improvement*, the irrational was developed into the rational.

The reader, however, will immediately perceive that when all the higher orders of plants and animals were thus supposed to be comparatively modern, and to have been derived in a long series of generations from those of more simple conformation, some further hypothesis became indispensable, in order to explain why, after an indefinite lapse of ages, there were still so many beings of the simplest structure. Why have the majority of existing creatures remained stationary throughout this long succession of epochs, while

others have made such prodigious advances? Why are there such multitudes of infusoria and polyps, or of confervæ and other cryptogamic plants? Why, moreover, has the process of development acted with such unequal and irregular force on those classes of beings which have been greatly perfected, so that there are wide chasms in the series; gaps so enormous, that Lamarck fairly admits we can never expect to fill them up by future discoveries?

The following hypothesis was provided to meet these objections. Nature, we are told, is not an intelligence, nor the Deity; but a delegated power—a mere instrument—a piece of mechanism acting by necessity—an order of things constituted by the Supreme Being, and subject to laws which are the expressions of His will. This Nature is *obliged* to proceed gradually in all her operations; she cannot produce animals and plants of all classes at once, but must always begin by the formation of the most simple kinds, and out of them elaborate the more compound, adding to them, successively, different systems of organs, and multiplying more and more their number and energy.

This Nature is daily engaged in the formation of the elementary rudiments of animal and vegetable existence, which correspond to what the ancients termed *spontaneous generation*. She is always beginning anew, day by day, the work of creation, by forming monads, or 'rough draughts' (ébauches), which are the only living things she gives birth to *directly*.*

There are distinct primary rudiments of plants and animals, and *probably* of each of the great divisions of the animal and vegetable kingdoms.† These are gradually developed into the higher and more perfect classes by the slow but unceasing energy of two influential principles: first, *the tendency to progressive advancement* in organisation, accompanied by greater dignity in instinct, intelligence, &c.; secondly, *the force of external circumstances*, or of variations in the physical condition of the earth, or the mutual relations of plants and animals. For, as species spread them-

* Phil. Zool: pp. 65 and 204.

† Animaux sans Vert., tom. i. Introduction, p. 56 note.

selves gradually over the globe, they are exposed from time to time to variations in climate, and to changes in the quantity and quality of their food; they meet with new plants and animals which assist or retard their development by supplying them with nutriment, or destroying their foes. The nature, also, of each locality, is in itself fluctuating; so that, even if the relation of other animals and plants were invariable, the habits and organisation of species would be modified by the influence of local revolutions.

Now, if the first of these principles, *the tendency to progressive development*, were left to exert itself with perfect freedom, it would give rise, says Lamarck, in the course of ages, to a graduated scale of being, where the most insensible transition might be traced from the simplest to the most compound structure, from the humblest to the most exalted degree of intelligence. But, in consequence of the perpetual interference of the *external causes* before mentioned, this regular order is greatly interfered with, and an approximation only to such a state of things is exhibited by the animate creation, the progress of some races being retarded by unfavourable, and that of others accelerated by favourable, combinations of circumstances. Hence, all kinds of anomalies interrupt the continuity of the plan; and chasms, into which whole genera or families might be inserted, are seen to separate the nearest existing portions of the series.

Lamarck's theory of the transformation of the orang-outang into the human species.—Such is the machinery of the Lamarckian system; but the reader will hardly, perhaps, be able to form a perfect conception of so complicated a piece of mechanism, unless it is exhibited in action, so that we may see in what manner it can work out, under the author's guidance, all the extraordinary effects which we behold in the present state of the animate creation. Without attempting to follow the author through the entire process by which, after a countless succession of generations, a small gelatinous body is transformed into an oak or an ape, I shall pass on at once to the last grand step in the progressive scheme, by which the orang-outang, having been evolved out of a monad, is made slowly to attain the attributes and dignity of man.

One of the races of quadrumanous animals which had reached the highest state of perfection, lost, by constraint of circumstances, the habit of climbing trees, and of hanging on by grasping the boughs with their feet as with hands. The individuals of this race being obliged, for a long series of generations, to use their feet exclusively for walking, and ceasing to employ their hands as feet, were transformed into bimanous animals, and what before were thumbs became mere toes, no separation being required when their feet were used solely for walking. Having acquired a habit of holding themselves upright, their legs and feet assumed, insensibly, a conformation fitted to support them in an erect attitude, till at last these animals could no longer go on all-fours without much inconvenience.

The Angola orang (*Simia troglodytes*, Linn.) is the most perfect of animals; much more so than the Indian orang (*Simia Satyrus*), which has been called the orang-outang, although *both* are *very inferior* to man in corporeal powers and intelligence. These animals frequently hold themselves upright; but their organisation has *not yet* been sufficiently modified to sustain them habitually in this attitude, so that the standing posture is very uneasy to them. When the Indian orang is compelled to take flight from pressing danger, he immediately falls down upon all-fours, showing clearly that this was the original position of the animal. Even in man, whose organisation, in the course of a long series of generations, has advanced so much farther, the upright posture is fatiguing, and can be supported only for a limited time, and by aid of the contraction of many muscles. If the vertebral column formed the axis of the human body, and supported the head and all the other parts in equilibrium, then might the upright position be a state of repose; but, as the human head does not articulate in the centre of gravity, as the chest, belly, and other parts press almost entirely forward with their whole weight, and as the vertebral column reposes upon an oblique base, a watchful activity is required to prevent the body from falling.* Children who have large heads and prominent bellies can hardly walk at

* Phil. Zool. p. 353.

the end even of two years; and their frequent tumbles indicate the natural tendency in man to resume the quadrupedal state.*

Now, when so much progress had been made by the quadrumanous animals before mentioned, that they could hold themselves habitually in an erect attitude, and were accustomed to a wide range of vision, and ceased to use their jaws for fighting and tearing, or for clipping herbs for food, their snout became gradually shorter, their incisor teeth became vertical, and the facial angle grew more open.

Among other ideas which the natural *tendency to perfection* engendered, the desire of ruling suggested itself, and this race succeeded at length in getting the better of the other animals, and made themselves masters of all those spots on the surface of the globe which best suited them. They drove out the animals which approached nearest them in organisation and intelligence, and which were in a condition to dispute with them the good things of this world, forcing them to take refuge in deserts, woods, and wildernesses, where their multiplication was checked, and the progressive development of their faculties retarded; while, in the meantime, the dominant race spread itself in every direction, and lived in large companies, where new wants were successively created, exciting them to industry, and gradually perfecting their means and faculties.

In the supremacy and increased intelligence acquired by the ruling race, we see an illustration of the natural tendency of the organic world to grow more perfect; and, in their influence in repressing the advance of others, an example of one of those disturbing causes before enumerated, that *force of external circumstances* which causes such wide chasms in the regular series of animated being.

When the individuals of the dominant race became very numerous, their ideas greatly increased in number, and they felt the necessity of communicating them to each other, and of augmenting and varying the signs proper for the communication of ideas. Meanwhile the inferior quadrumanous animals, although most of them were gregarious, acquired

* Phil. Zool. p. 354.

no new ideas, being persecuted and restless in the deserts, and obliged to fly and conceal themselves, so that they conceived no new wants. Such ideas as they already had remained unaltered, and they could dispense with the communication of the greater part of these. To make themselves, therefore, understood by their fellows, required merely a few movements of the body or limbs—whistling, and the uttering of certain cries varied by the inflexions of the voice.

On the contrary, the individuals of the ascendant race, animated with a desire of interchanging their ideas, which became more and more numerous, were prompted to multiply the means of communication, and were no longer satisfied with mere pantomimic signs, nor even with all the possible inflexions of the voice, but made continual efforts to acquire the power of uttering articulate sounds, employing a few at first, but afterwards varying and perfecting them according to the increase of their wants. The habitual exercise of their throat, tongue, and lips, insensibly modified the conformation of these organs, until they became fitted for the faculty of speech.*

In effecting this mighty change, 'the exigencies of the individuals were the sole agents; they gave rise to efforts, and the organs proper for articulating sounds were developed by their habitual employment.' Hence, in this peculiar race, the origin of the admirable faculty of speech; hence also the diversity of languages, since the distance of places where the individuals composing the race established themselves soon favoured the corruption of conventional signs.†

In conclusion, it may be proper to observe that the above sketch of the Lamarckian theory is no exaggerated picture, and those passages which have probably excited the greatest surprise in the mind of the reader are literal translations from the original.

* Lamarck's Phil. Zool. tom. i. p. 356. † Ibid. p. 357.

CHAPTER XXXV

THEORIES AS TO THE NATURE OF SPECIES, AND DARWIN ON NATURAL SELECTION.

OBJECTIONS URGED AGAINST THE THEORY OF TRANSMUTATION AND LAMARCK'S REPLIES—MUMMIES OF ANIMALS AND SEEDS OF PLANTS FROM EGYPTIAN TOMBS IDENTICAL IN CHARACTER WITH SPECIES NOW LIVING—LINNÆUS' OPINION THAT SPECIES HAVE BEEN CONSTANT SINCE THEIR CREATION—BROCCHI'S HYPOTHESIS OF THE GRADUAL DIMINUTION OF VITAL POWER IN A SPECIES —WHETHER IF NEW SPECIES ARE CREATED FROM TIME TO TIME THEIR FIRST APPEARANCE MUST HAVE BEEN WITNESSED BY THE NATURALIST— GEOFFROY ST. HILAIRE AND LAMARCK ON RUDIMENTARY ORGANS—THE QUESTION OF SPECIES AS TREATED OF IN THE 'VESTIGES OF CREATION'—MR. ALFRED WALLACE ON THE LAW WHICH HAS REGULATED THE INTRODUCTION OF NEW SPECIES—MR. DARWIN ON NATURAL SELECTION AND MR. WALLACE ON THE SAME—DARWIN'S ORIGIN OF SPECIES AND THE CHANGE OF OPINION WHICH IT EFFECTED—DR. HOOKER'S FLORA OF AUSTRALIA AND HIS VIEWS AS TO THE ORIGIN OF SPECIES BY VARIATION.

Objections urged against the Theory of Transmutation and Lamarck's Replies.—The theory of the transmutation of species, considered in the last chapter, was received with some degree of favour by many naturalists, from their desire to dispense, as far as possible, with the repeated intervention of a First Cause, as often as geological monuments attest the successive appearance of new races of animals and plants, and the extinction of those pre-existing. But, independently of a predisposition to account, if possible, for a series of changes in the organic world by the regular action of secondary causes, we have seen that in truth many perplexing difficulties present themselves to all who attempt to establish the reality and constancy of the specific character. And if once there appears ground for reasonable doubt, in regard to the constancy of species, the amount of transformation which they are capable of undergoing might seem to resolve itself into a mere question of the quantity of time

assigned to the past and future duration of animate existence.

The opponents of Lamarck objected to his arguments that he could not adduce a single instance of the gradual conversion of any one species of animal or plant into another; and that in his appeal to the results obtained by the breeder and horticulturist, he had failed to show such a change in the structure and constitution of individuals descending from a common stock as might fairly entitle the new race to rank as a distinct species. It was conceded, for example, on all hands that the modifications produced in the different races of dogs exhibit the influence of man in the most striking point of view. These animals had been transported into every climate, and placed in every variety of circumstances: they had been made, as M. Dureau de la Malle observed, the servant, the companion, the guardian, and the intimate friend of man, and the power of a superior genius had had a wonderful influence not only on their forms, but on their manners and intelligence.* Different races have undergone remarkable changes in the quantity and colour of their clothing; the dogs of Guinea are almost naked, while those of the Arctic Circle are covered with a warm coat both of hair and wool, which enables them to bear the most intense cold without inconvenience. There are differences also of another kind no less remarkable, as in size, the length of their muzzles, and the convexity of their foreheads. 'The difference in stature,' said Cuvier, 'in some canine races as compared to others is as 1 to 5 in linear dimensions,' making a difference of a hundredfold in volume.†

But, said the advocates of the immutability of species, if we look for some essential changes, such as might serve as a foundation for the theory of Lamarck, respecting the growth of new organs and the gradual obliteration of others, we find nothing of the kind. In all the varieties of the dog, as Cuvier affirmed, the relation of the bones with each other remains essentially the same; the form of the teeth never changes in any perceptible degree, except that, in some

* Dureau de la Malle, Ann. des Sci. Nat., tom. xxi. p. 53, Sept. 1830.

† Cuvier, Discours Prélimin., p. 128.

individuals, one additional false grinder occasionally appears, sometimes on the one side, and sometimes on the other.* The greatest departure from a common type—and it constitutes the maximum of variation as yet known in the animal kingdom—is exemplified in those races of dogs which have a supernumerary toe on the hind foot with the corresponding tarsal bones; a variety analogous to one presented by six-fingered families of the human race.†

It was moreover urged, and of all objections this was the most serious, that however distinct were the various races of the dog, they could all breed freely together and produce fertile offspring, as was also the case with various domesticated birds, such as the common fowl, of which such marked varieties had been obtained. In no instance had the mongrel offspring been shown to be habitually sterile, like the common mule or the offspring of the horse and ass, where the two parents belong to two undoubtedly distinct species.

When the controversy had been brought to this point, and the amount of possible variation of animals under domestication, and of plants under culture, was still under discussion, the followers of Lamarck sometimes lamented that no accurate descriptions, and figures of known species, had been handed down from the earliest periods of history, such as might have afforded data for comparing the condition of the same species, at two periods considerably remote. To this, however, the opponents of transmutation replied, that we are in a great measure independent of such evidence, since, by a singular accident, the priests of Egypt have bequeathed to us, in their cemeteries, that information which the museums and works of the Greek and Roman philosophers have failed to transmit.

It had fortunately happened that the men of science who accompanied the French armies during their four years' occupation of Egypt, from 1797 to 1801, instead of employing their whole time, as so many preceding investigators had done, in exclusively collecting human mummies, had examined diligently and sent home great numbers of embalmed bodies of consecrated animals, such as the bull, the dog,

* Disc. Prél. p. 129, sixth edition. † Ibid.

the cat, the ape, the ichneumon, the crocodile, and the ibis.

They who have never raised their conceptions of the import of Natural History beyond the admiration of beautiful objects or the exertion of skill in detecting specific differences, would wonder at the enthusiasm expressed in Paris at the beginning of this century, amidst the din of arms and the stirring excitement of political events, in regard to these precious remains. In the official report, drawn up by the Professors of the Museum at Paris, on the value of the objects alluded to, the following passages might seem extravagant, unless we reflect how fully the reporters (Cuvier, Lacépède, and Lamarck) appreciated the bearing of the facts thus brought to light on the past history of the globe.

'It seems,' say they, 'as if the superstition of the ancient Egyptians had been inspired by Nature, with a view of transmitting to after ages a monument of her history. That extraordinary and eccentric people, by embalming with so much care the brutes which were the objects of their stupid adoration, have left us, in their sacred grottos, cabinets of zoology almost complete. The climate has conspired with the art of embalming to preserve the bodies from corruption, and we can now assure ourselves by our own eyes what was the state of a great number of species three thousand years ago. We can scarcely restrain the transports of our imagination, on beholding thus preserved, with their minutest bones, with the smallest portions of their skin, and in every particular most perfectly recognisable, many an animal, which at Thebes or Memphis, 2,000 or 3,000 years ago, had its own priests and altars.' *

'Among the Egyptian mummies thus procured were not only those of numerous wild quadrupeds, birds, and reptiles; but, what was perhaps of still higher importance in helping to decide the great question under discussion, there were the mummies of domestic animals, among which those above mentioned, the bull, the dog, and the cat, were frequent. Now, such was the conformity, says Cuvier, of the whole of these species and races to those now living, that there was

* Ann. du Muséum d'Hist. Nat. tom. i. p. 234. 1802.

no more difference between them than between the human mummies and the embalmed bodies of men of the present day. Yet some of these animals have since that period been transported by man to almost every variety of climate, and forced to accommodate their habits to new circumstances as far as their nature would permit. The cat, for example, has been carried over the whole earth, and, within the last three centuries, has been naturalised in every part of the New World—from the cold regions of Canada to the tropical plains of Guiana; yet it has scarcely undergone any perceptible mutation, and is still the same animal which was held sacred by the Egyptians. Of the ox, undoubtedly, there are many very distinct races; but the bull Apis, which was led in solemn processions by the Egyptian priests, did not differ from some of those now living.

Nor was the evidence derived from the Egyptian monuments confined to the animal kingdom; the fruits, seeds, and other portions of twenty different plants, were faithfully preserved in the same manner; and among these the common wheat was procured by Delille, from closed vessels in the sepulchres of the kings, the grains of which retained not only their form, but even their colour; so effectual had proved the process of embalming with bitumen in a dry and equable climate. No difference could be detected between this wheat and that which now grows in the East and elsewhere, and similar identifications were made in regard to many other plants.

In answer to the argument drawn from this class of facts Lamarck observed, that 'the animals and plants referred to had not experienced any modification in their specific characters, because the climate, soil, and other conditions of life had not varied in the interval. But if,' he went on to say, 'the physical geography, temperature, and other natural conditions of Egypt had altered as much as we know they have done in many countries in the course of geological periods, the same animals and plants would have deviated from their pristine types so widely as to rank as new and distinct species.'* This reply, when we consider its date (about the year 1809),

* Phil. Zool. pp. 70-71.

may well lay claim to our admiration, as it evinced Lamarck's thorough conviction, that geological changes are brought about so slowly that the lapse of thirty or forty centuries is utterly insignificant in the history of a species. Nearly all the men of science of his day, even the great majority of geologists, entertained extremely narrow views in regard to the duration of those periods of the past of which they were studying the archives. They were generally inclined to attribute all great changes of the earth's crust, and its inhabitants, to brief and violent catastrophes, against which Lamarck emphatically protested.* Yet neither he nor any of his contemporaries could as yet form any conception of the number and real magnitude of the revolutions in the animate world with which paleontology has since made us familiar. In certain passages of his work he admitted that possibly the Paleotherium, Anoplotherium, and some other fossil genera of quadrupeds then recently described by Cuvier as occurring in tertiary strata near Paris, may have disappeared, having, perhaps, been exterminated by the power of man. But in regard to smaller animals, especially those of the aquatic tribes, which could not have been the victims of human intervention, he sometimes expressed a doubt whether most of these may not still have their representatives surviving in regions unexplored by the naturalist. Being aware, however, that the specific and generic forms of animals and plants preserved in the rocks are more unlike those now existing in proportion as they are more ancient, Lamarck expressed his belief that in those cases where the fossil animals could be identified with the living, the strata containing them must be very modern, their descendants not having had time to vary, except within extremely narrow limits.†

It was by this constant reference to time as an essential element even in the definition of a species, that the teaching of Lamarck differed from that of Linnæus, Blumenbach, and Cuvier.

Linnæus on species.—Linnæus in one of his treatises had

* Phil. Zool. p. 80.

† Ibid. chap. iii., De l'Espèce, p. 79.

said that classes and orders are the inventions of science, but species are the work of nature.* In another place he went so far as to declare that genera, like species, are primordial creations.†

Expressions may doubtless be found in some of his speculative essays, implying that he thought that some species at least were the daughters of time, '*temporis filiæ*,' and we shall see in Chap. XXXVII. that when a great number of closely allied species existed in the same region, he strongly suspected that they might be derived from other species—possibly that they were hybrids, and had become so far permanent as to require to be treated as distinct species. But his deliberate opinion was contained in the following aphorism: 'We reckon just so many species as there were forms created in the beginning.' ‡ Blumenbach declared that 'no general rule can be laid down for determining the distinctness of species, as there is no particular class of characters which can serve as a criterion. In each case we must be guided by *analogy* and *probability*.'

In former editions of this work from 1832 to 1853, I did not venture to differ from the opinion of Linnæus, that each species had remained from its origin such as we now see it, being variable, but only within certain fixed limits. The mystery in which the origin of each species was involved seemed to me no greater than that in which the beginning of all vital phenomena on the earth is shrouded. But I undertook to show that the gradual extinction of species one after another was part of the constant and regular course of nature, and must have been so throughout all geological time, because the climate, and the position of land and sea, and all the principal conditions of the organic and inorganic world, are always, and have been always, undergoing change. I pointed out how the struggle for existence among species, and the increase and spread of some of them, must tend to the extermination of others; and as these would disappear gradually and singly from the scene, I suggested

* 'Classis et Ordo est sapientiæ, Species naturæ opus.'

† 'Genus omne est naturale, in primordio tale creatum,' &c. Phil. Bot. § 159. See also ibid. § 162.

‡ 'Totidem numeramus species quot in principio formæ sunt creatæ.'

that probably the coming in of new species would in like manner be successive, and that there was no geological sanction for the favourite doctrine of some theorists, that large assemblages of new forms had been ushered in at once to compensate for the sudden removal of many others from the scene.

Brocchi on the dying out of a species.—An Italian geologist, Brocchi, the author in 1814 of an able work on the fossil shells of the Subapennine Hills, endeavoured to imagine some regular and constant law by which species might be made to disappear from the earth gradually and in succession. The death, he suggested, of a species might depend, like that of individuals, on certain peculiarities of constitution conferred upon them at their birth; and as the longevity of the one depends on a certain force of vitality, which, after a period, grows weaker and weaker, so the duration of the other may be governed by the quantity of prolific power bestowed upon the species which, after a season, may decline in energy, so that the fecundity and multiplication of individuals may be gradually lessened from century to century, 'until that fatal term arrives when the embryo, incapable of extending and developing itself, abandons, almost at the instant of its formation, the slender principle of life by which it was scarcely animated,—and so all dies with it.'* In opposition to this doctrine, I contended that there is no reason to suspect that the last individuals of a species of which the numbers are diminishing are physiologically deteriorated, or are in the least degree impaired in their prolific powers; for there are known causes in the animate and inanimate world which must in the course of ages annihilate species, however vigorous their powers of reproduction might remain. As the death of the last representatives of a species would be abrupt, I conjectured that the birth of new forms might be equally so, but as I had entire faith in the doctrine that what is now going on in the natural world affords a true indication of what has been and will be, I assumed that the coming in of new species must be going on at about the same rate as the dying out of old ones; and I

* Brocchi, Conch. Foss. Subap., tome i. 1814.

therefore felt myself called upon to explain how the birth of new species could be always in progress, and yet the botanist and zoologist remain wholly unconscious of the occurrence of events so wonderful, and to them of such transcendent interest.

Assuming that species were specially created from time to time to fill up the gaps to which the never-ceasing changes of the animate and inanimate world must give rise, I enquired what kind of evidence we had a right to expect of the origin of new forms of animals and plants in the course of the last twenty or thirty centuries. Ought we to have been as conscious of the fact as we are of the lessening of the numbers and the occasional extermination of particular species? It was obviously, I remarked, more easy to prove that a species, once numerously represented in a given district, had ceased to be, than that some other which did not pre-exist had made its appearance—assuming always that single stocks only of each animal and plant are originally created, and that individuals of new species do not suddenly start up in many different places at once. The latter hypothesis had already been considered by Linnæus, and pronounced by him to be unphilosophical because quite unnecessary, since, as he observed, every animal or plant, even those which increase slowly, are capable in twenty or thirty generations of stocking a large part of the whole globe with their descendants.

So imperfect has the science of Natural History remained down to our own times, that, within the memory of persons now living, the numbers of known animals and plants have been doubled, or even quadrupled, in many classes. New and often conspicuous species are annually discovered in parts of the old continent, long inhabited by the most civilised nations. Conscious, therefore, of the limited extent of our information, we always infer, when such discoveries are made, that the beings in question had previously eluded our research; or had at least existed elsewhere, and only migrated at a recent period into the territories where we now find them. It is difficult to look forward to the time when we shall be entitled to make any other hypothesis in regard

to all the marine tribes, and to by far the greater number of the terrestrial; such as birds, and insects, and a large proportion of plants, especially those of the cryptogamous class, many of which possess such unlimited powers of diffusion as to be almost cosmopolitan in their range.

It may perhaps be said that if new species were suddenly called into being by special acts of creation, some forest tree or new quadruped ought to have been seen, for the first time, within the last ten or twenty centuries in the more populous parts of such countries as England or France. In that case, the naturalist might have been able to demonstrate that no similar living form had before existed in the district.

Now, although this argument may seem plausible, its force will be found to depend entirely on the rate of fluctuation which we suppose to prevail in the animate world, and on the proportion which such conspicuous subjects of the animal and vegetable kingdoms bear to those which are less known and escape our notice. There are perhaps more than a million species of plants and animals, exclusive of the microscopic and infusory animalcules, now inhabiting the terraqueous globe; so that if only one of these were to become extinct annually, and one new one were to be every year called into being, much more than a million of years might be required to bring about a complete revolution in organic life.

I have never ventured to hazard any precise hypothesis as to the probable rate of change; but none will deny that when the *annual* birth and the *annual* death of one species on the globe was proposed as a mere speculation, this at least was to imagine no slight degree of instability in the animate creation. If we divide the surface of the earth into twenty regions of equal area, one of these might comprehend a space of land and water about equal in dimensions to Europe, and might contain a twentieth part of the million of species which may be assumed to exist in the animal kingdom. In this region one species only would, according to the rate of mortality before assumed, perish in twenty years, or only five out of fifty thousand in the course of a century.

But as a considerable proportion of the whole would belong to the aquatic classes, with which we have a very imperfect acquaintance, we must exclude them from our consideration; and if they constitute half of the entire number, then one species only might be lost in forty years among the terrestrial tribes. Now the Mammalia, whether terrestrial or aquatic, bear so small a proportion to other classes of animals, forming less, perhaps, than one thousandth part of the whole, that if the longevity of species in the different orders were equal, a vast period must elapse before it would come to the turn of this conspicuous class to lose one of their number. If one species only of the whole animal kingdom died out in forty years, no more than one mammifer might disappear in 40,000 years in a region of the dimensions of Europe.

It is easy, therefore, to see, that in a small portion of such an area, in countries, for example, of the size of England and France, periods of much greater duration must elapse before it would be possible to authenticate the first appearance of one of the larger plants and animals, assuming the annual birth and death of one species to be the rate of vicissitude in the animate creation throughout the world. It would follow from the above considerations that if Lamarck was entitled to plead insufficiency of time when challenged to bring forward a single case of transmutation, the advocates of special creation were equally entitled to say that if the introduction of new species goes on as slowly as the extinction of old ones, it could not be expected that they should have witnessed the first starting into being of a new animal or plant.

Geoffroy St. Hilaire and Lamarck on rudimentary organs.— The great majority of the best naturalists and geologists who succeeded Lamarck were content to believe with Humboldt that the origin of species was one of those mysteries which it was not given to natural science to penetrate. Omalius d'Halloy, however, in his 'Elements of Geology,' which he published in 1831, and in six subsequent editions, taught that the species of animals now living were the descendants of progenitors which have left their fossil remains in the later Tertiary formations. I asked him in the year 1867, when

he was in his eighty-fourth year, by what facts and reasonings he had been led to entertain this view, and he told me that he owed his convictions on this head to the lectures of Geoffroy St. Hilaire, to which he had listened in the early part of this century at Paris. That great zoologist, he said, never lost an opportunity, when he spoke of the rudimentary organs found in so many animals, of pointing out their bearing on the theory of transmutation. According to him they were clearly the relics of parts which had been serviceable in some remote ancestor and had been reduced in size by disuse, and he rejected the idea as puerile that useless organs had been created for the sake of uniformity of plan.

I may here remark that in my brief abstract of Lamarck's theory drawn up by me originally in 1832, and which for reasons explained in the last chapter (p. 248, note) I have now reprinted without alteration or addition, I omitted, when referring to what he had said on the impoverishment and final disappearance of organs by disuse, to cite many examples which he gives in the 'Philosophie Zoologique' in illustration of this principle. Among other facts the abortive teeth concealed in the jaws of some mammalia are mentioned, such teeth not being required because their food is swallowed without mastication. The discovery also by G. St. Hilaire of teeth in the fœtus of a whale is alluded to, and the small size of the eyes in the mole, which makes scarcely any use of its organs of vision. Allusion is also made to the aquatic reptile called *Proteus anguinus*, inhabiting the waters of dark subterranean caverns, which retains only the vestiges or rudiments of eyes.*

The question of species as treated in the 'Vestiges of Creation.'—But, speaking generally, it may be said that all the most influential teachers of geology, paleontology, zoology, and botany continued till near the middle of this century either to assume the independent creation and immutability of species, or carefully to avoid expressing any opinion on this important subject. In England the calm was first broken by the appearance in 1844 of a work entitled 'The Vestiges of Creation,' in which the anonymous author had gathered

* Phil. Zool. tom. i. p. 240, where other examples are also given.

together and presented to the public, with great clearness and skill, the new facts brought to light in geology and the kindred sciences since the time of Lamarck in favour of the transmutation of species and their progressive development in time. He availed himself of the generalisations of paleontologists on the changes observable in the fossil fauna and flora of successive epochs of the past, showing that the structural affinity was greatest in those which stood nearest each other in position when the strata were arranged in chronological order, and that there had been a gradual approximation of the animate world as it changed from period to period to the state of things now represented by the living creation.

The embryological investigations of Tiedemann and others were referred to as being in harmony with the doctrine of transmutation; the various phases of development through which a mammifer passes when in the fœtal state representing in succession the likeness of a fish, reptile and bird, and lastly putting on the characters proper to the highest class of vertebrata. It was also suggested that these metamorphoses were comparable to the creative additions made in like chronological order to the organic world of past ages as revealed to us by the fossil remains preserved in the rocks. The arguments which Lamarck and others had derived from rudimentary organs in favour of their views were re-stated and their validity emphatically insisted upon. The unity of plan exhibited by the whole organic creation fossil and recent, and the mutual affinities of all the different classes of the animal and vegetable kingdoms, were declared to be in harmony with the idea of new forms having proceeded from older ones by generation, species having been gradually modified by the influence of external conditions.

Lamarck had rendered his hypothesis very complete by embracing without any essential change the notions of Aristotle as to spontaneous generation. The simplest rudiments or germs of life were assumed to be always coming into being. This would account for the present abundance of species of the lowest grades of animal and vegetable existence in spite of the constant advance throughout past time of the

organic creation towards a more perfect state. In his eagerness to supply the evidence which was wanting to confirm the reality of the working of this part of the plan of nature, the author of the 'Vestiges' displayed an extraordinary want of philosophical caution. For he cited experiments which were supposed to prove that the action of a voltaic pile on a solution of potash could give origin to new species of insects. The careless way in which these experiments had been conducted contrasted in a striking manner with the extreme caution displayed by those who had been endeavouring to test the truth or falsehood of Harvey's dictum that 'every living thing comes from an egg.' The result of every increase in the power of the microscope had been to refute the theory of spontaneous generation, or at least to force the abettors of the old doctrine to take refuge in the obscure region of the infinitely minute. Distrust of the soundness of the author's judgment was also engendered by a suspicion that he was not practically versed in the study of any one department of natural knowledge. Every weak point, moreover, in this treatise was exposed with unsparing severity by critics who were impatient of the popularity it enjoyed, notwithstanding the adoption by the author of Lamarck's doctrine that Man was not only the last link of a long series of progressive developments, but had been connected by descent with the inferior animals.

Darwin and Wallace on the origin of species.—The next important effort to determine the manner in which new species may have originated was made in 1855 by Mr. Alfred Wallace in the 'Annals of Natural History,'* in an essay entitled 'On the Law which has regulated the Introduction of New Species.' The opinions enounced in this paper carried with them the authority of one who was well versed in several departments of natural history, especially ornithology and entomology. He had first explored during four years, conjointly with Mr. H. W. Bates, the valley of the river Amazons, and the neighbouring equatorial parts of South America, their expedition having been

* Series 2, vol. xvi. Republished in 'Contributions to the Theory of Natural Selection,' p. 1.

expressly undertaken to collect facts 'towards solving the problem of the origin of species.'* Mr. Wallace had afterwards spent many years in studying the zoology of the Malay Archipelago, devoting his attention especially to the birds and insects; and the result of his experience, aided by the information obtained from geological writers, was summed up in the following proposition, 'that every species has come into existence coincident both in space and time with a pre-existing closely allied species.'† Mr. Darwin,‡ when referring subsequently to this paper in his 'Origin of Species,' has stated that he knew from correspondence with Mr. Wallace that the cause to which he attributed the coincidence here alluded to was no other than 'generation with modification,' or, in other words, the 'closely allied antitype' was the parent stock from which the new form had been derived by variation. All the most telling arguments which Lamarck had brought forward, and those drawn from various sources which the 'Vestiges' had superadded, in favour of species being the result of indefinite modification, instead of special creation, were briefly and ably summed up by Mr. Wallace; but it was clear that the evidence which had most powerfully influenced his mind, was that derived from his own experience of the geographical distribution of species, and especially of birds and insects.

In geography, he remarked, a genus or species rarely occurs in two very distant localities without being also found in the intermediate space; so in geology the life of a genus or species is not interrupted, no species having come into existence twice, or having been renewed after having once died out. For the manner in which the gradual extinction of species had been brought about and was still in progress, Mr. Wallace referred to my chapter on that subject in the 'Principles of Geology,' confining his speculations to the manner in which new forms were introduced from time to time to replace those which were lost.

Meanwhile Mr. Charles Darwin, well known by his 'Voyage in the Beagle,' and various works on Geology, had been for

* Bates' Preface to his 'Naturalist on the River Amazons.'

† Annals of Nat. Hist. ser. 2, vol. xvi. p. 186.

‡ 1st ed. p. 355; 4th ed. p. 424.

many years busily engaged in collecting materials for a great work on the origin of species; having made for that purpose a vast series of original observations and experiments on domesticated animals and cultivated plants, and having reflected profoundly on those problems in geology and biology which were calculated to throw most light on that question. For eighteen years these researches had all been pointing to the same conclusion, namely, that the species now living had been derived by variation and generation from those which had pre-existed, and these again from others of still older date. Several of his MS. volumes on this subject had been read by Dr. Hooker as long ago as 1844, and how long the ever-accumulating store of facts and reasonings might have remained unknown to the general public, had no one else attempted to work out the same problem, it is impossible to say. But at length Mr. Darwin received a communication, dated February 1858, from Mr. Wallace, then residing at Ternate in the Malay Archipelago, entitled 'On the Tendency of Varieties to depart indefinitely from the Original Type.'

The Author requested Mr. Darwin to show this essay to me should he think it sufficiently novel and interesting. It was brought to me by Dr. Hooker, who remarked how complete was the coincidence of Mr. Wallace's new views and those contained in one of the chapters of Mr. Darwin's unpublished work. Accordingly, he suggested that it would be unfair to let Mr. Wallace's essay go to press unaccompanied by the older memoir on the same subject. Although, therefore, Mr. Darwin was willing to waive his claim to priority, the two papers were read on the same evening to the Linnæan Society and published in their Proceedings for 1858. The title of the chapter extracted from Mr. Darwin's MS. ran as follows: 'On the Tendency of Species to form Varieties, and on the Perpetuation of Species and Varieties by Natural Means of Selection.'

Already in the previous year, September 1857, Mr. Darwin had sent to Professor Asa Gray, the celebrated American botanist, a brief sketch of his forthcoming treatise on what he then termed 'Natural Selection.' This letter, also printed by the Linnæan Society together with the papers above alluded

to, contained an outline of the leading features of his theory of selection as since explained, showing how new races were formed by the breeder, and how analogous results might or must occur in nature under changed conditions in the animate and inanimate world. Reference was made in the same letter to the law of human population first enunciated by Malthus, or the tendency in man to increase in a geometrical ratio, while the means of subsistence cannot be made to augment in the same ratio. We were reminded that in some countries the human population has doubled in twenty-five years, and would have multiplied faster if food could have been supplied. In like manner every animal and plant is capable of increasing so rapidly, that if it were unchecked by other species, it would soon occupy the greater part of the habitable globe; but in the general struggle for life few only of those which are born into the world can obtain subsistence and arrive at maturity. In any given species those alone survive which have some advantage over others, and this is often determined by a slight peculiarity capable in a severe competition of turning the scale in their favour. Notwithstanding the resemblance to each other and to their parents of all the individuals of the same family, no two of them are exactly alike. The breeder chooses out from among the varieties presented to him those best suited to his purpose, and the divergence from the original stock is more and more increased by breeding in each successive generation from individuals which possess the desired characters in the most marked degree. In this manner Mr. Darwin suggests that as the surrounding conditions in the organic and inorganic world slowly alter in the course of geological periods, new races which are more in harmony with the altered state of things must be formed in a state of nature, and must often supplant the parent type.

Although this law of natural selection constituted one only of the grounds on which Mr. Darwin relied for establishing his views as to the origin of species by variation, yet it formed so original and prominent a part of his theory that the fact of Mr. Wallace having independently thought out the same principle and illustrated it by singularly analogous

examples, is remarkable. It raises at the same time a strong presumption in favour of the truth of the doctrine. Both writers referred to the number of the feathered tribe which perish annually. 'Very few birds,' says Mr. Wallace, 'produce less than two young ones each year, while many have six, eight, or ten; and if we suppose that each pair produce young only four times in their life, each would at this rate increase in fifteen years to nearly ten millions, whereas we have no reason to believe that the number of the birds of any country increases at all in fifteen or even in 150 years. It is evident, therefore, that each year an immense number of birds must perish, as many in fact as are born; and as on the lowest calculation the progeny are each year twice as numerous as their parents, it follows that whatever be the average number of individuals existing in any given country, twice that number must perish annually.

'Large broods are superfluous: on the average all above one become food for hawks and kites, wild cats and weazels, or perish of cold and hunger as winter comes on.'* The most remarkable instance of an immense bird population is that of the passenger pigeon of the United States, 'which lays only one or at most two eggs, and is said to rear generally but one young one. Why is this bird so extraordinarily abundant, while others producing two or three times as many young are much less plentiful? The explanation is not difficult. The food most congenial to this species, and on which it thrives best, is abundantly distributed over a very extensive region, offering such differences of soil and climate, that in one part or another of the area the supply never fails. The bird is capable of very rapid and long-continued flight, so that it can pass without fatigue over the whole of the district it inhabits, and as soon as the supply of food begins to fail in one place is able to discover a fresh feeding-ground. This example strikingly shows us that the procuring a constant supply of wholesome food is almost the sole condition requisite for ensuring the rapid increase of a given species, ... neither the limited fecundity, nor the unrestrained

* ... of Linnæan Soc., vol. iii. p. 55. 1858. 'Contributions to Natural ... p. 30.

attacks of birds of prey and of man, are here sufficient to check it.' *

When pointing out how every variation from the typical form of a species gives an advantage to some individuals over others, Mr. Wallace shows that even a change of colour, by rendering certain animals more or less distinguishable, affects their safety. He also observes that in a state of nature, a race better fitted for changed conditions would never revert to the form which it had displaced; although in the case of domesticated animals allowed to run wild or become 'feral,' they must, to a certain extent, recover the character which they had lost during their subjugation to man, for reasons which will be explained in Chapter XXXVII. The essay concluded with some judicious criticisms on Lamarck's notion that animals may by their own efforts promote the development of some of their organs, or even acquire new ones. 'Changes,' says Mr. Wallace, 'have been brought about, not by the volition of the creatures themselves, but by the survival of varieties which had the greatest facilities of obtaining food. The giraffe did not acquire its long neck by desiring to reach the foliage of lofty trees and by constantly stretching out its neck for that purpose, but varieties which occurred with a longer neck than usual had an advantage over their shorter-necked companions, and, on the first scarcity of food, were enabled to survive them.' †

After the publication of the detached chapter of his book in the Linnæan Proceedings, Mr. Darwin was persuaded by his friends that he ought no longer to withhold from the world the result of his investigations on the nature and origin of species, and his theory of Natural Selection. Great was the sensation produced in the scientific world by the appearance of the abridged and condensed statement of his views comprised in his work entitled 'On the Origin of Species by means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.' From the hour of its appearance it gave, as Professor Huxley truly said, 'a

* Journ. of Linnæan Soc., vol. iii. p. 55. 1858. 'Contributions to Natural Selection,' p. 42.

† Journ. of Linnæan Soc. p. 61. 'Contributions to Natural Selection,' p. 42.

new direction to biological speculation,' for even where it failed to make proselytes, it gave a shock to old and time-honoured opinions from which they have never since recovered. It effected this not merely by the manner in which it explained how new races and species might be formed by Natural Selection, but also by showing that, if we assume this principle, much light is thrown on many very distinct and otherwise unconnected classes of phenomena, both in the present condition and past history of the organic world.

Hooker on variation and selection and the formation of species in the vegetable world.—The abandonment of the old received doctrine of the 'immutability of species' was accelerated in England by the appearance, in the same year (1859), of Dr. Hooker's essay on the Flora of Australia. In several of his previous writings this eminent botanist had said all that could be said in support of the 'constancy of the specific character in the vegetable world.' He had been freely discussing for fifteen years with Mr. Darwin, all the facts and arguments which they could bring to bear on this question, but he stated in his Introduction, that until the views of his friend and those of Mr. Wallace in favour of Natural Selection had been made known, he scarcely felt himself at liberty frankly to declare how far, as a botanist, he was prepared to go in the same direction. He had been occupied for more than twenty years in the study of plants of various parts of the world, arctic, temperate, and tropical, insular and continental. He had personally explored the floras of several of these regions, had described and classified thousands of species, and was well known to unite caution with boldness in his philosophical speculations. From his new essay the general public learnt, not without surprise, how little the most experienced botanists are agreed amongst themselves as to the limits of species, and to what an extent these limits are a mere matter of opinion, even amongst those who believe that species have remained unchanged since their creation, and will remain immutable as long as they continue on the globe. As conspicuous evidence of this he stated that the number of known

species of flowering plants is assumed by some to be under 80,000, and by others over 150,000.*

Dr. Hooker showed that in proportion as we study the same plant under varied conditions and in distant regions, it becomes more and more difficult to define its precise specific characters; also that in the flora of every country there are some groups of species which are apparently unvarying, others which on the contrary run so much one into another that the whole group may be regarded as a continuous series of varieties between the terms of which no hiatus exists such as might allow of the intercalation of any intermediate variety. The genera Rubus, Rosa, Salix, and Saxifraga afford conspicuous examples of these unstable forms; Veronica, Campanula, and Lobelia of comparatively stable ones. At the same time he points out in accordance with Mr. Darwin's theory how the extinction of a certain number of the intermediate races by destroying the transitional links would facilitate the classification of the remaining species, and hints that we may be indebted to such extinction in past times for whatever facility we now enjoy of resolving plants into distinct species, genera, and orders. 'The mutual relations,' he observes, 'of the plants of each great botanical province, and in fact, of the world generally, are just such as would have resulted if variation had gone on operating throughout indefinite periods, in the same manner as we see it act in a limited number of centuries, so as gradually to give rise in the course of time to the most widely divergent forms.'

When we reflect that this statement was made after a study of the characters and geographical distribution of tens of thousands of species, we feel disposed at once to declare that a theory which is in harmony with so many facts must be true; but if so, we have to enquire how it happens that so many naturalists, of undoubted ability and knowledge, have always held and still believe that species have been constant from the beginning. In reference to this question, Dr. Hooker admits that species are realities and may be treated as if they were permanent and immutable; for the forms and characters, at least of the great majority of them, may be

* Flora of Tasmania, p. iii.

faithfully transmitted through thousands of generations, and may have remained constant within the range of our experience. 'But our experience,' he remarks, 'is so limited that it will not account for a single fact in the present geographical distribution, or origin of any one species of plant, nor for the amount of variation it has undergone, nor will it indicate the time when it first appeared nor the form it had when created.' *

* Hooker, Flora of Tasmania.

CHAPTER XXXVI.

VARIATION OF PLANTS AND ANIMALS UNDER DOMESTICATION VIEWED AS BEARING ON THE ORIGIN OF SPECIES.

DOMESTIC RACES, HOWEVER DIVERGENT, BREED FREELY TOGETHER—REMOTE ANTIQUITY OF SOME ARTIFICIALLY FORMED RACES—SELECTION, BOTH UNCONSCIOUS AND METHODICAL, VERY INFLUENTIAL IN FORMING NEW RACES—THE CHARACTERS OF SOME RACES OF THE DOMESTICATED PIGEON OF GENERIC VALUE—REVIVAL OF LONG-LOST CHARACTERS IN THE OFFSPRING OF CROSS-BREEDS—MULTIPLE ORIGIN OF THE DOG—INHERITED INSTINCTS—VARIATION OF THE GOLD FISH AND SILKWORM—MAN CAUSES PARTICULAR PARTS OF AN ANIMAL OR PLANT TO VARY WHILE OTHER PARTS CONTINUE UNALTERED—MAIZE—CABBAGE—ARE THERE ANY LIMITS TO THE VARIABILITY OF A SPECIES?—OBEDIENCE TO MAN UNDER DOMESTICATION OFTEN MERELY A NEW ADAPTATION OF A NATURAL INSTINCT—'FERAL' VARIETIES DO NOT REVERT TO THE EXACT LIKENESS OF THE ORIGINAL WILD STOCK—HOW FAR DO DOMESTIC RACES DIFFER FROM WILD SPECIES IN THEIR CAPACITY TO INTERBREED?—HYBRIDISATION OF ANIMALS AND PLANTS—HERMAPHRODITE PLANTS NOT USUALLY SELF-FERTILISED—WHETHER THE DISTINCTNESS OF SPECIES CAN BE TESTED BY HYBRIDITY—TENDENCY OF DIFFERENT RACES OF DOMESTIC CATTLE AND SHEEP TO HERD APART—PALLAS ON DOMESTICITY ELIMINATING STERILITY—CORRELATION OF GROWTH.

DOMESTIC RACES, HOWEVER DIVERGENT, BREED FREELY TOGETHER.—We have seen that the indefinite modifiability of species in the course of thousands of generations, and under gradually altered conditions in the organic and inorganic world, is a question which has been seriously entertained by naturalists ever since the beginning of the present century. The changes brought about by the breeder and horticulturist, and the new races to which they have given origin, have always been appealed to in support of this theory of unlimited variability. It may be said that man, in every stage of his social progress, has been engaged in conducting, with much patience and at enormous cost, a grand series of experiments to ascertain how far it is possible to make the descendants of common parents, both in the animal and vegetable kingdoms, deviate from their original type. In pur-

suing this course he has by no means confined his attention to plants and animals which minister to his wants, but he has sometimes gone on for thousands of years simply for his amusement, trying how far he could alter certain species —the pigeon, for example, or some flowering plants such as the rose.

The opponents of the doctrine of transmutation have always objected to arguments founded on the results of such experiments, that, in spite of the skill and perseverance of the breeder, agriculturist, and florist, man has never succeeded in giving origin to one new species. For however far some of the new races may have diverged from the parent stock or from each other, they have always continued to breed freely together and produce fertile offspring, whereas the hybrids which result from the union of two distinct species in nature are always sterile.

Before we can decide on the weight which we must attach to such an objection, we must consider not only the nature and extent of the changes which have been effected in species under domestication and culture, but also the facility of obtaining hybrid plants and animals of wild species, and the different degrees of sterility of the hybrids when obtained. The whole subject of the variation of domesticated animals and cultivated plants has been lately treated of, with so much ability and in such detail, by Mr. Darwin in his work on Variation,* that I cannot do better than refer the reader to his clear statements of the facts and of their bearing on his theory of the 'Origin of Species.' In this chapter, besides repeating much that I advanced in former editions, I shall allude briefly to some of the valuable observations and experiments which he has made, and the theoretical conclusions to which they point.

Remote antiquity of some artificially formed races.—The explorations so actively carried on within the last twenty years in the Swiss lake-dwellings, and an examination of the remains of animals and plants there preserved, have shown that domesticated races of the dog, the ox, and the sheep, and cultivated varieties of several cereals and of many fruits,

* The Variation of Plants and Animals under Domestication: 1867.

had been formed in Central Europe in the Neolithic age, or before the use of metals was yet general. The antiquity which we are thus called upon to assign to the culture of certain plants need not surprise us, if Mr. Darwin is correct in his opinion that man in a barbarous state is naturally led to discover the useful properties of all wild plants by the frequently recurring famines to which all savage tribes are exposed; for when in danger of starving he is compelled to try as food every kind of fruit, leaf, and root. By this means the nutritious, stimulating, and medical qualities of the most unpromising species are brought to light.

It might have been thought that the seeds of wild grasses were too minute to afford much temptation for men in a rude state of society to cultivate them for food; but it seems that both Barth and Livingstone* observed the natives in different parts of Africa collecting the seeds of wild grasses, and eating them; from which practice it would be an easy step to pass to the sowing of some of them near their usual haunts, and eventually to the selection for seed of those varieties which yielded the largest crops. The great number of cultivated grasses or cereals, and the difficulties which botanists encounter when they endeavour to trace them to their original stocks, or to the wild species from which they have sprung, become more intelligible if we suppose that they have undergone considerable modifications under culture in prehistoric times.

It has often been remarked that we do not owe a single useful plant to Australia or the Cape of Good Hope, or to New Zealand, or to America south of the Plata. On this subject Mr. Darwin observes, that we must by no means infer that in these countries no native plants have proved useful to savage man. Dr. Hooker, indeed, enumerates no less than 107 native species† which are used even by the Australians. But the small advantage which civilised man has hitherto derived from the regions above alluded to simply demonstrates that wild plants cannot compete with those which have been improved by cultivation for a long series of generations.

* Cited by Darwin 'On Variation of Animals,' &c., 1867, p. 308.

† Flora of Australia, Introduction, p. cx.

A skilful botanist who should see for the first time our finest varieties of apples, peaches, pears, and plums, would be unable to guess from what species of wild trees they had been derived.

De Candolle mentions no less than thirty-three useful plants which we owe to Mexico, Peru, and Chili, among which the maize and potato are conspicuous; and Tschudi describes two forms of maize no longer known in Peru, which were taken from the tombs of the Incas,* and which had become extinct before the arrival of the Spaniards in South America. But strange to say, no botanist has yet been able to trace the maize, which had evidently been cultivated from a very remote period, to any wild aboriginal parent stock.

The slowness with which improved varieties of native plants have been brought into existence may be inferred from the researches of Oswald Heer with respect to the fruits belonging to the Swiss lake-dwellers of the later Stone period. They had collected wild crabs, sloes, bullaces, elderberries, hips of roses and beech-mast differing but slightly from those which we know in a wild state. They had also five kinds of wheat and three of barley, mostly inferior in size to ours. Among them was the wheat commonly called Egyptian; a fact leading to the inference that the lake-dwellers had either come originally from the south or had intercourse with some southern people. So in regard to the domesticated animals of the same lake-dwellers, they do not agree exactly with any of our breeds. Thus for example, they had two kinds of cattle which are considered as modifications of two species or races which then existed in a wild state—namely, *Bos primigenius* and *Bos longifrons*; but, although they were modifications of these original types, they cannot be identified with any existing European breeds. Their dog also differed from ours, or from that of the later Bronze period, and according to Rütimeyer was of a middle size, and equally remote from the wolf and the jackal. They had also a small breed of sheep with long and thin legs and with horns like those of a goat, which was not exactly similar to any one of the races now known.

Selection, both unconscious and methodical, very influential

* Cited by Darwin 'On Variation,' &c., p. 320.

in forming new races.—When the art of the breeder has been greatly perfected, he is able to bring about very important changes in a short time. He has no power either of causing or preventing the numerous varieties which nature presents to him among individuals born of the same parents. But he can choose those which best suit his purpose, and breed from them, while he destroys those varieties which are less valuable. In the next generation he again picks out those individuals which possess the desired qualities in a somewhat more marked degree; and so goes on accumulating these differences till he produces a breed which answers to some preconceived idea formed by him. He can discriminate trifling variations both in animals and plants which an uneducated eye cannot appreciate. The variations which are thus intensified become fixed by inheritance, and permanent races are formed by a process technically called 'selection.' But there is another kind of selection, termed 'unconscious' by Mr. Darwin, which perhaps acts more powerfully in the long run, both in a rude and civilised state of society. The savage, when pressed by hunger, is often driven to feed on his dogs; in which case, if he is able to retain any of them, he preserves such as are most useful to him in the chase. So in a very early state of agriculture, the seeds and fruits of those varieties which offer some advantage over others, by the abundance of their produce or the quality or flavour of the nutriment they afford, will be sown by preference, whereas the seeds of less prized varieties will be consumed. For man is always called upon to decide which individuals shall be spared as a stock from which to breed, so many more being always born into the world than there is room or food for. Mr. Darwin supposes that, even in the most advanced state of society, the influence of unconscious selection acts more powerfully than methodical selection.

Our present bull-dogs, he observes, are different from those formerly used for baiting bulls, being of smaller size and altered in shape, now that the old sport has been given up. Our fox-hounds differ from the old English hound, and our greyhounds have become lighter. Our enormous dray-horses have been produced from some ancient bulky race through

the unconscious selection, carried on during many generations in Flanders and England, of the most powerful and heaviest horses, without the least intention or expectation of creating our present elephant-like breed.* After the introduction into England of some Arab horses, the methodical selection of the swiftest individuals gradually produced the English race-horse. But even this change has been partly effected unconsciously, by the general wish to breed as fine horses as possible, without any intention to give to them their present character.

The characters of some races of the domesticated pigeon of generic value.—Domestic pigeons afford a most striking illustration of the great divergence from the original type, the rock pigeon (*Columba Livia*), which man has brought about in the course of time. These birds have been domesticated for thousands of years in Egypt and India, and they afford remarkable facilities for the production of distinct breeds, as the male and female birds can be easily mated for life, and the different varieties kept together in the same aviary. More than 150 distinct races have received names, all breeding true; and at least a score of these, says Mr. Darwin, might be named, which, if shown to an ornithologist, and he was told they were wild birds, would be ranked by him as well-defined species, while some of them, such as the carrier, short-faced tumbler, pouter and fan-tail, would not even be placed in the same genus. From historical details which have come down to us of the principal races of the pigeon as they were known in India before the year 1600, it appears that these races, although they might have been classed in the same groups as our present breeds, had not at that time diverged in so great a degree from their aboriginal common parent, the wild rock pigeon.

Pigeon-fanciers in forming new varieties have confined their attention to external characters—such as the length of the beak, the number or length of the tail feathers, the colour of the plumage, and the general shape of the body, yet they have sometimes unintentionally produced modifications in

* Darwin 'On Variation,' chap. xx. p. 212.

the internal bony framework of the species. Thus while they have given a longer body to the pouter, they have unintentionally augmented the number of its sacral and caudal vertebræ, and the breadth of the ribs as well as the size of the breast-bone. In the fan-tail they have increased considerably the length and number of the caudal vertebræ; and, what is still more worthy of note, in several breeds the whole skull differs in its proportions and outline from that of the rock pigeon.

So many passages have been traced between the most divergent varieties above alluded to and the wild *Columba Livia*, that ornithologists do not hesitate to recognise this species as the common progenitor of them all. Another curious proof of such a derivation is afforded by crossing distinct breeds and finding in the offspring some peculiar characters of the rock pigeon, especially in the plumage, which neither of the parent races possessed.* Thus the blue slaty colour, or dark bars, on the wings and tail, and the white edging of the outer tail feathers of the original *Columba Livia*, are produced in the mongrel offspring of the carrier and fan-tail, although all these characters have often been in abeyance in both of the parent stocks for a hundred or more generations. Mr. Darwin has tested the truth of this singular principle of atavism, by experiment, in the case of pigeons, and has also obtained analogous results, by pairing some of the most distinct varieties of the common fowl; as, for example, a black Spanish cock and a white silky hen, two ancient and pure breeds in which there was not a trace of the red colour proper to the plumage of the wild *Gallus bankiva*, a Himalayan species, which has always been supposed to be the original of our domestic fowls. In many of the young obtained from such a cross the peculiar orange-red colour was conspicuous.†

Revival of long-lost characters in the offsprings of cross-breeds.—Why the act of crossing should tend to evoke characters which had long been lost in each of the parent races, is one of the most wonderful enigmas which the attributes of

* Darwin 'On Variation.' vol. i. p. 200. † Ibid. p. 241.

inheritance present to us. By what favourable combination of circumstances can we suppose these characters, which must have been lying latent in so many intermediate generations, to be thus made again to manifest themselves? In some cases they are developed alternately in successive generations, in others at longer intervals.

The composition of the molecules which form the germ-cells of animals and plants, and their mode of multiplication and transmission from one generation to another, has been a favourite subject of speculation ever since the time of Buffon and Bonnet. More recently (1849), Professor Owen has treated of this subject in his memoir on 'Parthenogenesis,' and Mr. Herbert Spencer has speculated on the manner in which the atoms or physiological units composing the fertilised germ of an animal or plant may unfold into organisms and become the means of transferring the qualifications of the parent to the offspring.* The new hypothesis suggested by Mr. Darwin, and which he has called 'Pangenesis,' coincides in many respects with that of Mr. Spencer, and cannot be fully understood without reference to the luminous and detailed explanations of it given by Darwin in the concluding chapters of his work on Variation.† He assumes that the germ-cells of animals and plants are capable of generating minute bodies, termed by him cell-gemmules, which become diffused through all parts of an organism, and are capable of multiplying and uniting with others like themselves, and when this union does not occur, may remain in a dormant state. Their increase may take place after the usual manner of growth in all living beings, according to which entire limbs are sometimes reproduced in the lower animals after they have been cut off, or as wounds are healed by the formation of new flesh, or as a portion of the leaf of a plant may be developed into a perfect individual. The cell-gemmules remaining undeveloped for many generations, may be compared to seeds lying dormant in the earth, or to rudimentary organs which, though useless, may be inherited for an indefinite succession of generations, or as long as an entire species endures on the earth.

* Principles of Biology, vol. i. chaps. iv. and viii.

† Darwin 'On Variation' chaps xxxvii. and xxxviii.

Before this new hypothesis was started, it was sufficiently difficult to conceive how a microscopic cell or ovule, so minute as to be often invisible to the naked eye, and in some cases requiring the aid of a powerful microscope to be made visible, should contain within it not only the characters of the species, but many of the peculiarities of one or both parents, including some of their acquired individual habits and instincts. But now we are called upon, in addition, to imagine that there are innumerable other molecules, in each germ or ovule, in which the characteristics of remote progenitors may also be present. As bearing on the question of the possible minuteness of particles of organic matter, I shall have to refer in a future chapter (Chap. XL.) to the ten million sporules of a single fungus which were counted by Fries. A still more lively idea of the possible diminutiveness of material atoms may be gained by reflecting on the manner in which the air is often perfumed or tainted throughout large spaces by the odour of a plant or animal, and how the contagious particles of certain diseases float unseen in the atmosphere, until they are at last received within a human body, where they rapidly increase and act powerfully.

Assuming, then, that the number of cell-gemmules in an undeveloped embryo may be almost infinite in number, we have to explain how some of these, after having been long transmitted in a latent state, may suddenly multiply and gain an ascendancy when individuals belonging to two distinct races are crossed. Among other facts which are somewhat analogous, we are reminded that, although there is frequently in the offspring a fusion of all the characters of the parents, yet occasionally some of the characters of one parent are exclusively transmitted to one of the children and those of the other parent to another. The characters of one parent sometimes prevail in all the offspring to the exclusion of those of the other. When Gärtner crossed white and yellow-flowered varieties and species of mullein (*verbascum*), these colours never became blended, but the offspring bore either pure white or pure yellow blossoms. This must depend on some principle of the affinity of similar and the repulsion of dissimilar atoms. The cell-germs derived from two

individuals of distinct races may not readily unite, or not in sufficient numbers for the reproduction of the characteristic attributes of the two parents; they may be antagonistic and neutralise each other's power in such a way as to allow the gemmules derived from a remote progenitor to multiply suddenly, gaining such an ascendancy as to revive certain peculiarities of the original stock which had remained long in abeyance.

Multiple origin of the dog.—In regard to the origin of the various canine races which have been domesticated by man in all parts of the world, there is still no small diversity of opinion. Mr. Darwin, after an elaborate analysis of all that has been written on the subject, inclines to the belief which Pallas entertained of the multiple origin of the dog, more than one wild species having been blended together to produce the very distinct races which we now possess. The celebrated John Hunter maintained that the wolf, the dog, and the jackal were all of one species; because he had found, by two experiments, that the dog would breed both with the wolf and the jackal; and that the mule, in each case, would breed again with the dog. In these cases, however, it may be observed, that there was always one parent at least of pure breed, and no proof was obtained that a true hybrid race could be perpetuated.

It was formerly supposed that the period of gestation in the dog and the wolf differed slightly; but experiments have not borne out this opinion; and Professor Owen has been unable to confirm the alleged difference in the structure of a part of the intestinal canal. It seems scarcely to admit of a doubt that both the jackal, and more than one species of wolf, have been occasionally crossed with the dog.

The main argument in favour of the different breeds of the dog being the descendants of distinct wild stocks is their resemblance, says Darwin, in various countries to indigenous species still existing there.* Thus the domestic dogs of the American Indians resemble North American wolves. The shepherd-dog of Hungary is very like the European wolf; the domestic dog of Asia resembles the jackal. But Mr.

* Darwin 'On Variation,' chap. i. p. 20.

Wallace has suggested to me that evidence of this nature loses much of its weight when we take into consideration some cases of modification given by him and by Mr. Darwin, and cited by Mr. Mivart in his 'Genesis of Species.'* Many quite distinct species of butterflies are shown to be similarly modified in the same localities; in some districts acquiring more elongate wings, in others losing their tails, in others again becoming enlarged or diminished in size. No less than twenty-nine kinds of American trees have been shown by Mr. Meehan to differ from their nearest European allies, all in the same manner; and M. Costa has stated that young English oysters taken to the Mediterranean at once altered their manner of growth, and formed prominent diverging rays or ribs on the shell, like those proper to the Mediterranean oyster. A yet more pertinent illustration of this law is afforded by the Cape hunting dog (*Lycaon venaticus*), and the Aard wolf (*Proteles cristatus*), animals which inhabit the same region as the hyænas, and curiously resemble them in external form and colouring, although differing from hyænas in such important structural characters, that the former is placed in a distinct genus, and the latter constitutes, according to Professor Flower, a peculiar and very isolated family. If, therefore, certain localities can impress upon whole groups of species a uniform *facies*, Mr. Wallace considers it more probable that the dogs of various regions have been thus modified so as to correspond to native foxes, wolves, and jackals, than that they should have been descended from such very distinct species, and have mysteriously acquired the power of breeding together and producing fertile offspring, which those species themselves do not possess.

But, even if the intercrossing of several original wild stocks may have increased the total number and diversity of our breeds, it cannot, says Darwin, explain the origin of such extreme forms as thoroughbred greyhounds, bloodhounds, bulldogs, Blenheim spaniels, terriers and pugs, none of which are known to have been kept by savages, and which are the product of breeding in civilised countries. The difference

* Pp. 83–88.

in the form of the skulls in some of these races is admitted by Cuvier to be sometimes more than generic; in some varieties there is an additional pair of molars in the upper jaw (see p. 265); and some, like the Turkish dogs, are deficient in the number of their molars; the mammæ also vary from seven to ten in number. Dogs have properly five toes in front, and four behind, but a fifth toe is often added, together with a fourth cuneiform bone. Man, says Darwin, if he had cared about the number of their molar teeth, mammæ or digits, could, by selection, have fixed these characters, in the same way as he has given additional horns to certain breeds of sheep, and an additional toe and feathers to the Dorking fowl; but at present these peculiarities have merely accompanied changes in form, fleetness, size, strength, and other characters which the breeder has purposely fixed.

Inherited instincts.—It is evident that these new races could not be artificially produced if the individual peculiarities of one generation were not transmitted by inheritance to the next. Even newly acquired habits and instincts are often so transmitted, as was beautifully illustrated by a race of dogs employed for hunting deer in the platform of Santa Fé, in Mexico. The mode of attack, observes M. Roulin, which they employ consists in seizing the animal by the belly and overturning it by a sudden effort, taking advantage of the moment when the body of the deer rests only upon the fore-legs. The weight of the animal thus thrown over is often six times that of its antagonist. The dog of pure breed inherits a disposition to this kind of chase, and never attacks a deer from before while running. Even should the deer, not perceiving him, come directly upon him, the dog steps aside and makes his assault on the flank; whereas other hunting dogs, though of superior strength, and general sagacity, which are brought from Europe, are destitute of this instinct. For want of similar precautions, they are often killed by the deer on the spot, the vertebræ of their neck being dislocated by the violence of the shock.*

A new instinct has also become hereditary in a mongrel

* M. Roulin, Ann. des Sci. Nat., tom. xvi. p. 16. 1829.

race of dogs employed by the inhabitants of the banks of the Magdalena almost exclusively in hunting the white-lipped pecari. The address of these dogs consists in restraining their ardour, and attaching themselves to no animal in particular, but keeping the whole herd in check. Now, among these dogs some are found, which, the very first time they are taken to the woods, are acquainted with this mode of attack; whereas, a dog of another breed starts forward at once, is surrounded by the pecari, and, whatever may be his strength, is destroyed in a moment.

Some of our countrymen engaged about the year 1825 in conducting one of the principal mining associations in Mexico, that of Real del Monte, carried out with them some English greyhounds of the best breed, to hunt the hares which abound in that country. The great platform which is here the scene of sport is at an elevation of about 9,000 feet above the level of the sea, and the mercury in the barometer stands habitually at the height of about nineteen inches. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey, they lay down gasping for breath; but these same animals have produced whelps which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down the hares with as much ease as the fleetest of their race in this country.

The fixed and deliberate stand of the pointer has with propriety been regarded as a mere modification of a habit, which may have been useful to a wild race accustomed to wind game, and steal upon it by surprise, first pausing for an instant, in order to spring with unerring aim. The faculty of the retriever, however, may justly be regarded as more inexplicable and less easily referable to the instinctive passions of the species. M. Majendie, says a French writer in a recently published memoir, having learnt that there was a race of dogs in England which stopped and brought back game of their own accord, procured a pair, and, having obtained a whelp from them, kept it constantly under his eyes, until he had an opportunity of assuring himself that,

without having received any instruction, and on the very first day that it was carried to the chase, it brought back game with as much steadiness as dogs which had been schooled into the same manœuvre by means of the whip and collar.

The power of man to produce new races of animals by selection, has been by no means confined to the mammalia and birds. The Chinese have kept gold fish (*Cyprinus auratus*) for ornament or curiosity from a remote period, and it is suspected that the golden colour is not characteristic of the species in a state of nature. Yarrell mentions that descriptions and coloured drawings of no less than 89 varieties have been given by Sauvigny, some destitute of dorsal fins, others having a double anal fin or a triple tail. Of these, many, says Darwin, may be called monstrosities, for it is difficult to draw a strict line between a variation and a monstrosity.

If we turn from the vertebrata to the invertebrata, we find here again that selection is capable of producing distinct races in the class of insects, as in the case of the common silk-moth (*Bombyx mori*), which is believed to have been domesticated in China nearly 3,000 years before our era. It was brought to Constantinople in the sixth century, whence it was carried into Italy, and in the year 1494 into France.* The nature of the food given to the caterpillar influences to a certain extent the character of the breed. Great care is taken in India and Europe in the selection of the eggs of those moths whose caterpillars have produced the best cocoons. The silk is usually yellow, but sometimes white, and, by careful selection, in the course of sixty-five generations the proportion of yellow cocoons in France was greatly reduced. The abdominal feet of the caterpillars which yield white cocoons are, according to Quatrefages, always white, while the feet of those which give yellow cocoons are invariably yellow, and there is a corresponding difference in the tint of the eggs.

Man causes particular parts of an animal or plant to vary

* Godron 'De l'Espèce,' 1859, tom. i. p. 460; and see Darwin 'On Variation,' vol. i. p. 300.

while other parts may continue unaltered.—The possibility of obtaining particular breeds and fixed varieties of animals and plants depends on the fact that variations occur in almost any required direction if a vast number of individuals are produced. It is also found that one form of variation may usually be accumulated in successive generations by selection, without the other characters of the species being materially affected. Cows are wanted which may give us an increased quantity of milk, sheep which may yield finer wool, poultry which may have a habit of continually laying eggs; and these qualities are often obtained without perceptibly changing in any other respect the habits or organisation of the same races.

In the case of the maize and the vine, we alter the seed and the fruit without changing the leaves, whereas in the foliage of the mulberry, cultivated for the sake of the silkworm, new varieties have been formed, the fruit remaining the same. In the cabbage the leaves have undergone wonderful transformations, as have the tubers in the potato and the roots in the carrot, while the characters of the flowers in all have remained unaltered. The modifications produced in the seeds of the maize deserve especial notice. The different races vary in height from eighteen inches to as many feet, and the whole ear in one variety is more than four times as long as in another dwarf kind. The seeds are coloured white, pale yellow, orange, red, violet, or streaked with black. Mr. Darwin found that a single grain in one variety equalled in weight seven grains of another. The tall kinds grown in southern latitudes and exposed to great heat require from six to seven months to ripen their seed, whereas the dwarf kinds grown in northern and colder climates require only from three to four months.*

In North America the maize has been gradually cultivated farther and farther northward, in which case the changes induced by an alteration of climate have been added to those due to selection. In this plant the results of inherited acclimatisation are very striking. Metzger obtained the

* Metzger die Getreidearten, 1841, p. 206, cited by Darwin 'On Variation,' vol. i p. 321.

seed of a variety called *Zea altissima* from the warmer parts of America, and raised it in Germany, and the first year the plants were twelve feet high and few seeds were perfected. The lower seeds in the ear kept true to their proper form, but the upper ones became slightly changed. In the second generation the plants were from nine to ten feet in height, and the seeds had changed from white to yellow and were more rounded in form. In the third generation nearly all resemblance to the original and very distinct parent form was lost. In the sixth generation this maize, which continued to be cultivated near Heidelberg, could only be distinguished from the common European kind by a somewhat more vigorous growth. 'The fact,' says Mr. Darwin, 'affords the most remarkable instance known to me of the direct and prompt action of climate on a plant.'

Several hundred varieties of the vine, characterised by differences in their fruit, have been reared in hothouses, or cultivated for wine, while the mulberry, both in France and India, has given rise to as many varieties in the texture and quality of the leaves, characters which have been rendered constant by selection. If man had reversed this treatment, he might doubtless have produced endless changes in the leaves of the vine, the grapes remaining unaltered, and a great many races characterised by different fruits in the mulberry, while the leaves, being neglected, would not have undergone any marked modification from the type of the original plant.

A bitter plant (*Brassica oleracea*), with wavy sea-green leaves, having a flower like mustard or wild charlock, has been taken from the sea-side, and transplanted into the garden, where it has lost its saltness, and has been metamorphosed into many distinct vegetables, among others the red cabbage and the cauliflower, which are as unlike each other as is each to the parent plant. In certain countries plants belonging to the order of Cruciferæ which are generally herbaceous become developed into trees, so the cabbage in the island of Jersey has acquired a woody stem not unfrequently from ten to twelve feet in height. The stalk of one which measured sixteen feet in height had its spring shoots at the top occu-

pied by a magpie's nest. The wood of the same variety is sometimes used for walking sticks, and even for rafters. These effects result from particular culture and peculiarities of climate. What is worthy of note, says Darwin, is the very trifling difference in the flowers, seed-pods, and seeds of the cabbage which accompanies the wonderful metamorphosis which man has brought about in the shape, size, colour, and growth of the leaves and stem. What a contrast is here presented to the changes in the corresponding parts in the varieties of maize and wheat! 'The explanation is obvious: the seeds alone are valued in our cereals, and their variations have been selected; whereas the seeds, seed-pods, and flowers have been utterly neglected in the cabbage, whilst many useful variations in their leaves and stems have been noticed and preserved from an extremely remote period, for cabbages were cultivated by the old Celts.'*

Among the changes in external conditions of which florists avail themselves in order to produce new varieties those of the soil must not be overlooked. The production of blue instead of red flowers in the *Hydrangea hortensis*, illustrates the immediate effect of certain soils on the colours of the calyx and petals. In garden-mould or compost, the flowers are invariably red; in some kinds of bog-earth they are blue; and the same change is always produced by a particular sort of yellow loam.

Whether there are definite limits to the variability of a species.—In former editions of this work (from 1831 to 1853),† I contended that there are limits to that deviation from an original type of which species are susceptible. My argument was founded chiefly on the rapid rate at which we may bring about considerable modifications in a brief period in domesticated animals and cultivated plants, and the slow progress which we can afterwards make in modifying the same races when our experiments are persevered in for a great many generations. In illustration of this principle I observed, that when man uses force or stratagem against wild animals, the persecuted race soon becomes more cau-

* Darwin 'On Variation,' vol. i. p. 324.

† 'Principles of Geology,' 1st edition, 1831, vol. ii. chap. iii. p. 37, and 9th edition, chap. xxxv. p. 592.

tious, watchful, and cunning; new instincts seem often to be developed, and to become hereditary in the first two or three generations: but let the skill and address of man increase, however gradually, no farther variation can take place, no new qualities are elicited by the increasing dangers. The alteration of the habits of the species has reached a point beyond which no ulterior modification is possible, however indefinite the lapse of ages during which the new circumstances operate. Extirpation then follows, rather than such a transformation as could alone enable the species to perpetuate itself under the new state of things.

But Mr. Darwin has shown that even in those species such as the pigeon, our common cattle, sheep or pigs, which have been made to vary by selection from the remotest periods, there are no signs of a positive limit having been reached beyond which no farther change can be brought about. All have been altered within quite modern times, and 'the tendency to general variability seems unlimited.'*

It has also been pertinently remarked by Mr. Wallace that the amount of change in any one direction may at first be comparatively rapid; as when in the case of the race-horse, we begin to select certain varieties with a view of increasing speed, and afterwards fail in our efforts materially to raise the standard, for however many years we may expend wealth and energy in the attempt. The real question, he observes, is not whether indefinite and unlimited change in any or all directions is possible, but whether man can bring about such differences as do occur in nature by accumulating variations or by selection. 'All the swiftest animals—deer, antelopes, hares, foxes, lions, leopards, horses, zebras, and many others—have reached very nearly the same degree of speed. Although the swiftest of each must have been for ages preserved and the slowest must have perished, we have no reason to believe that there is any advance of speed. The possible limit under existing conditions, and perhaps under possible terrestrial conditions, has been long reached.'† But in the English race-

* Darwin 'On Variation,' &c., p. 416.

† Wallace, Quart. Journ. of Science, October, 1867, p. 486; and 'Contributions to the Theory of Natural Selection, p. 292.

horse we have been enabled to produce a variety surpassing in swiftness its own wild progenitor and all the other equine species.

Obedience to man under domestication often a mere adaptation of a natural instinct.—We may also very easily exaggerate the amount of change which seems to be brought about in a few generations. Frederick Cuvier* has clearly pointed out one source of deception relating to alterations which we may fancy we have wrought in the instincts and dispositions of animals. An animal in domesticity, he observes, is not essentially in a different situation, in regard to the feeling of restraint, from one left to itself. It lives in society without constraint, because, without doubt, it was a social animal; and it conforms itself to the will of man, because it had a chief, to which, in a wild state, it would have yielded obedience. There is nothing in its new situation that is not conformable to its propensities; it is satisfying its wants by submission to a master, and makes no sacrifice of its natural inclinations. All the social animals, when left to themselves, form herds more or less numerous; and all the individuals of the same herd know each other, are mutually attached, and will not allow a strange individual to join them. In a wild state, moreover, they obey some individual, which, by its superiority, has become the chief of the herd. Our domestic species had, originally, this sociability of disposition; and no solitary species, however easy it may be *to tame it*, has yet afforded true domestic races. We merely, therefore, develope, to our own advantage, propensities which propel the individuals of certain species to draw near to their fellows.

The sheep which we have reared is induced to follow us, as it would be led to follow the flock among which it was brought up; and, when individuals of gregarious species have been accustomed to one master, it is he alone whom they acknowledge as their chief—he only whom they obey. 'The elephant allows himself to be directed only by the carnac whom he has adopted; the dog itself, reared in solitude with its master, manifests a hostile disposition towards all others; and everybody knows how dangerous it is to be

* Mém. du Mus. d'Hist. Nat.; Jameson, Ed. New Phil. Journ., Nos. 6, 7, 8.

in the midst of a herd of cows, in pasturages that are little frequented, when they have not at their head the keeper who takes care of them.

'Everything, therefore, tends to convince us, that formerly men were only, with regard to the domestic animals, what those who are particularly charged with the care of them still are—namely, members of the society which these animals form among themselves; and, that they are only distinguished, in the general mass, by the authority which they have been enabled to assume from their superiority of intellect. Thus, every social animal which recognises man as a member, and as the chief of its herd, is a domestic animal. It might even be said, that, from the moment when such an animal admits man as a member of its society, it is domesticated, as man could not enter into such a society without becoming the chief of it.'*

But the ingenious author whose observations I have here cited, admits that the obedience which the individuals of many domestic species yield indifferently to every person, is without analogy in any state of things which could exist previously to their subjugation by man. Each troop of wild horses, it is true, has some stallion for its chief, who draws after him all the individuals of which the herd is composed; but, when a domesticated horse has passed from hand to hand, and has served several masters, he becomes equally docile towards *any person*, adopting as it were the whole human race as his leader.

Every troop of wild elephants has a leader who directs their movements with much caution, and takes care that none of them straggle from the herd. In India this animal rarely breeds in captivity, although, according to Mr. Crawfurd, in Ava, where the females are allowed to roam somewhat freely in the forests, they breed in a half-domestic state. In general it is found to be the best economy to capture full-grown individuals in a wild state, and in a few years after they are taken, sometimes, it is said, in a few months, their education is completed. They who have had oppor-

* Mém. du Mus. d'Hist. Nat.

tunities of observing them in their native forests are by no means surprised at the sagacity which they display after they have accommodated themselves to the society of man, to whom they render obedience, not by acquiring any new instincts, but simply in conformity to faculties proper to them in a wild state.

The tameness of some animals—in the case of cattle, goats, and deer, for example—after they have been reclaimed and improved by selection for two or three generations, is another change of which we may be in danger of overrating the importance. The first savages who wandered into new districts probably found most of the animals free from any apprehension of danger from man. Mr. Darwin relates that in the islands of the Galapagos Archipelago, placed directly under the equator, and nearly 600 miles west of the American continent, all the terrestrial birds, as the finches, doves, hawks, and others, are so tame that they may be killed with a switch. One day, says this author, 'a mocking-bird alighted on the edge of a pitcher which I held in my hand, and began quietly to sip the water, and allowed me to lift it with the vessel from the ground.' Yet formerly, when the first Europeans landed, and found no inhabitants in these islands, the birds were even tamer than now: already they are beginning to acquire that salutary dread of man which in countries long settled is natural even to young birds, which have never received any injury. So in the Falkland Islands, both the birds and foxes are entirely without fear of man; whereas, in the adjoining mainland of South America, many of the same species of birds are extremely wild; for there they have for ages been persecuted by the natives.*

Sir John Richardson informs us, in his able history of the habits of the North American animals, that, 'in the retired parts of the mountains, where the hunters had seldom penetrated, there is no difficulty in approaching the Rocky Mountain sheep, which there exhibit *the simplicity of character so remarkable in the domestic species;* but where they have been often fired at, they are exceedingly wild, alarm their companions, on the approach of danger, by a hissing noise, and

* Darwin's Journ. in Voyage of H.M.S. Beagle, p. 475.

scale the rocks with a speed and agility that baffle pursuit.' *

'Feral' varieties do not revert to the exact likeness of the original stock.—It is an old and received opinion that if any domesticated animals or cultivated plants are abandoned by man and allowed to run wild or become 'feral,' they will revert to the exact likeness of their aboriginal parent stock. But this seems to be only true to a limited extent. It was before remarked (p. 281) that such 'feral' animals can only compete with their fellows in the struggle for life by losing most of the characters which they have acquired in a state of domesticity.

Our quickly fattening pigs, says Mr. Wallace, our short-legged sheep, cattle without horns and pouter pigeons, would soon be annihilated if man's protection was withheld from them. In a few generations the boar when compelled to search for food recovers his long tusks and the full exercise of all his organs; reverting in the general shape of his body, the length of his legs and of his muzzle, to the type of the wild boar.

His reversion to the likeness of the parent stock, says Darwin, is probably more complete than that of other domesticated animals which run wild, but there is no evidence to show that it is ever perfect. There are two main types of the domestic pig—one supposed to come from the European *Sus scrofa*, and the other from the Indian *Sus Indica*. These varieties or species seem not yet to have been distinctly recognised in a feral state, and the feral pigs of S. America, Jamaica, and New Granada, have each some peculiarities.† Under new climatal and other conditions they vary, but they can only stand their ground by reacquiring many lost characters which belonged to the original wild species.

It is very commonly believed that when the seeds of fruit-trees and garden vegetables spring up in uncultivated soils, the plants revert to the likeness of the original wild stock; but Dr. Hooker observes that this is not strictly true. 'They degenerate and sometimes die out; sometimes they become stunted, and so far resemble their wild progenitors, but they

* Fauna Boreali Americana, p. 273. † Darwin 'On Variation,' chap. iii.

do not revert to the original type. Thus the Scotch kail and Brussels sprouts, if neglected, become as unlike the wild *Brassica Oleracea* as they are unlike one another; and our finer kind of apples, if grown from seed, degenerate and become crabs, but in so doing, they become crab states of the varieties to which they belong, and do not revert to the original wild crab-apple; and the same is true to a great extent of cultivated roses, and of the raspberry, strawberry, and most garden fruits.'* This experienced botanist therefore concludes that the characters of a variety are never so entirely obliterated that it has no longer a claim to be considered a variety.

How far do domestic races differ from wild species in their capacity to interbreed?—Hybridisation of animals and plants.— It is now time to return to a question which was mooted at the commencement of this chapter, namely, the freedom with which all artificially produced races breed together, and how far this clearly constitutes a real difference between them and the most closely allied wild species.

There are no less than 288 wild species of the pigeon family (*Columbidæ*); † yet, although some of these approach very near to others in their characters, they will not, so far as experiments have yet been tried, pair together, presenting in this respect a marked contrast to those domestic races which, as before stated (p. 290), would, if found wild, have been ranked by ornithologists as true species, yet which pair freely and produce fertile offspring.

All the different races of domestic dogs breed together, and John Hunter's opinion has already been cited, that the jackal and wolf must be classed as of the same species because when crossed they produce fertile mules. A capability of thus breeding together has often been proposed, as the best practical test of a real distinctness of species. The experiment with which we are most familiar relates to the mixed offspring of the horse and the ass; and in this case it is well established that the he-mule can generate and the she-mule produce. Such cases occur in Spain and Italy, and

* Hooker, 'Flora of Australia,' p. ix.

† C. L. Bonaparte, cited by Darwin, 'On Variation, p. 133.

much more frequently in the West Indies and New Holland; but these mules seldom breed in warm countries, still more rarely in temperate regions, and never in cold climates; and no instance is known of two such mules, male and female, having bred together.

The hybrid offspring of the she-ass and the stallion, the γίννος of Aristotle, and the hinnus of Pliny, differs from the mule, or the offspring of the ass and mare. In both cases, says Buffon, these animals retain more of the dam than of the sire, not only in the magnitude, but in the figure of the body; whereas, in the form of the head, limbs, and tail, they bear a greater resemblance to the sire. It seems rarely to happen that any hybrids are truly intermediate in character between the two parents. Thus Hunter mentions that, in his experiments with the dog and the wolf, one of the hybrid pups resembled the wolf much more than did the rest of the litter, and we are informed by Wiegmann, that, in a litter obtained in the Royal Menagerie at Berlin, from a white pointer and a she-wolf, two of the cubs resembled the common wolf-dog, but the third was like a pointer with hanging ears.

The phenomena of hybridity in plants present a remarkable parallel to those in the animal kingdom; and we have learnt more from the cultivators of plants, because they have been able to conduct their experiments on a grander scale, sowing great numbers of the two species which they desire to cross, and taking small account of failures, provided that some of the results of crossing are successful.

The first accurate experiments in illustration of this curious subject appear to have been made by Kölreuter, who obtained a hybrid from two species of tobacco, *Nicotiana rustica* and *N. paniculata*, which differ greatly in the shape of their leaves, the colour of the corolla, and the height of the stem. The stigma of a plant of *N. rustica* was fertilised with the pollen of a plant of *N. paniculata*. The seed ripened, and produced a hybrid which was intermediate between the two parents, and which, like all the hybrids which this botanist brought up, had imperfect stamens. He afterwards impregnated this hybrid with the pollen of *N. paniculata*, and

obtained plants which much more resembled the last. This he continued through several generations, until, by due perseverance, he actually changed the *Nicotiana rustica* into the *Nicotiana paniculata*.

The plan of crossing adopted was the cutting off of the anthers of the plant intended for fructification before they had shed pollen, and then laying on foreign pollen upon the stigma. The same experiment has since been repeated with success by Wiegmann, who found that he could bring back the hybrids to the exact likeness of either parent, by crossing them a sufficient number of times with individuals of one of the pure stocks.

The blending of the characters of parent stocks, in many other of Wiegmann's experiments, was complete; the colour and shape of the leaves and flowers, and even the scent, being often intermediate. An intermarriage, also, between the common onion and the leek (*Allium cepa* and *A. porrum*) gave a mule plant, which, in the character of its leaves and flowers, approached most nearly to the garden onion, but had the elongated bulbous root and smell of the leek.

The same botanist remarks, that vegetable hybrids, when not strictly intermediate, more frequently approach the female than the male parent species; *but they never exhibit characters foreign to both.* A re-cross with one of the original stocks generally causes the mule plant to revert towards that stock; but this is not always the case, the offspring sometimes continuing to exhibit the character of a full hybrid.

Gärtner, in his work on the hybridisation of plants, has shown that some pure species which can be united with unusual facility will produce sterile hybrids, while others which are crossed rarely, or with extreme difficulty, produce hybrids which are very fertile, as for example in different species of the genus *Dianthus* or pink. The same botanist repeatedly crossed the common red and blue pimpernels, *Anagallis arvensis* and *A. cærulea*, which, says Darwin, the best naturalists rank as mere varieties of one species, and found them absolutely sterile. These plants, besides their distinctness in colour, differ slightly in the nervation of their leaves and in the shape of their petals; and botanists who

attach importance to the test of sterility conclude that they are specifically distinct, although scarcely any of them would have come to such an opinion before the experiment of crossing had been tried.

Wiegmann diversified as much as possible his mode of bringing about these irregular unions among plants. He often sowed parallel rows, near to each other, of the species from which he desired to breed; and, instead of mutilating, after Kölreuter's fashion, the plants of one of the parent stocks, he merely washed the pollen off their anthers. The branches of the plants in each row were then gently bent towards each other and intertwined; so that the wind, and numerous insects, as they passed from the flowers of one to those of the other species, carried the pollen and produced fecundation.

When we consider how busily many insects are engaged in conveying anther-dust from flower to flower, especially bees, flower-eating beetles, and the like, it seems a most enigmatical problem how it can happen that promiscuous alliances between distinct species are not perpetually occurring.

How continually do we observe the bees diligently employed in collecting on their hind legs the red and yellow powder with which the stamens of flowers are covered, and, after passing from one flower to another, carrying it to their hive for the purpose of feeding their young! In thus providing for their own progeny, these insects assist materially the process of fructification.* Few persons need be reminded that the stamens in certain plants grow on different blossoms from the pistils; and, unless the summit of the pistil be touched with the fertilising dust, the fruit does not swell, nor the seed arrive at maturity. It is by the help of bees, moths, and other insects, that the development of the fruit of many such species is secured, the powder which they have collected from the stamens being unconsciously left by them in visiting the pistils.

A vast amount of plants are hermaphrodite, yet Mr. Darwin, following up the views suggested by Andrew Knight,

* See Barton 'On Geography of Plants,' p. 67.

has proved experimentally that even with such plants the intermarriage of two separate individuals gives more vigour and fertility to the offspring than if the female organs are fertilised by the pollen of males of the same individual. The whole arrangement of the flower may seem to be made for the purpose of close interbreeding, and yet insects and other means are employed by nature for crossing the hermaphrodite with another individual of the same species.

How often, during the heat of a summer's day, do we see the males of diœcious plants, such as the yew-tree, standing separate from the females, and sending off into the air, upon the slightest breath of wind, clouds of buoyant pollen! That the zephyr should so rarely intervene to fecundate the plants of one species with the anther-dust of others, seems almost to realise the converse of the miracle believed in by the credulous herdsmen of the Lusitanian mares—

> Ore omnes versæ in Zephyrum, stant rupibus altis
> Exceptantque leves auras: et sæpe sine ullis
> Conjugiis, vento gravidæ, mirabile dictu.*

Mr. Darwin has discovered that when a flower is fertilised by the wind, it never has a gaily coloured corolla; but when its fertilisation depends on the aid of insects, the flowers are conspicuous in colour and size, evidently in order to attract their observation.†

When we consider the facility with which the skilful gardener produces hybrid races, it seems strange that we do not oftener meet with hybrids in a state of nature. But it must be remembered that the conditions in the two cases are very different.

The stigma imbibes, slowly and reluctantly, the granules of the pollen of another species, even when it is abundantly covered with it; and if it happen that, during this period, ever so slight a quantity of the anther-dust of its own species alight upon it, this is instantly absorbed, and the effect of the foreign pollen destroyed. Besides, it does not often happen that the male and female organs of fructification, in different species, arrive at a state of maturity at precisely the same

* Georg. lib. iii. 273. † Origin of Species, 4th edition, p. 239.

time. Even where such synchronism does prevail, so that a cross impregnation is effected, the chances are very numerous against the establishment of a hybrid race.

The greater part even of those seeds of wild plants which are well ripened are either eaten by insects, birds, and other animals, or decay for want of room and opportunity to germinate. Unhealthy plants are the first which are cut off by causes prejudicial to the species, being usually stifled by more vigorous individuals of their own kind. If, therefore, the relative fecundity or hardiness of hybrids be in the least degree inferior, they cannot maintain their footing for many generations in a wild state. In the universal struggle for existence, the right of the strongest must eventually prevail; and the strength and durability of a race depend in a great degree on its prolificness, in which hybrids are acknowledged to be generally deficient.

It is admitted on all hands, that in proportion as the species of animals and plants are remote from each other in structure they are averse to sexual union; and that species which the zoologist and botanist would usually class as distinct, most commonly refuse to unite, and if they can be crossed and produce offspring, the hybrids are sterile. Whenever we find that two races regarded by many as true species will produce fertile hybrids, we are reduced to the dilemma of choosing between two alternatives; either to reject the test of hybridity, or to declare that the two species, from the union of which the fruitful progeny has sprung, were mere varieties. If we prefer the latter, we are compelled to question the reality of the distinctness of all other supposed species which differ no more than the parents of such prolific hybrids; for although we may not be enabled immediately to procure, in all such instances, a fruitful offspring, yet experiments show that sometimes, after repeated failures, the union of two recognised species may at last, under very favourable circumstances, give birth to a fertile progeny.

Two kinds of pheasant, our common species, *Phasianus colchicus*, and *P. torquatus*, breed together, and the hybrids

are perfectly fertile.* The two pimpernels, as before stated (p. 309), cannot be crossed.

Tendency of different races of domestic cattle and sheep to herd apart.—Although more than one species of wolf as well as the jackal have been crossed with the dog (see p. 294), and this mixture is supposed to have contributed somewhat to the great diversity of our artificial breeds, yet these same wolves and the jackal keep distinct in a wild state. So also more than one of the aboriginal races or sub-species of European wild cattle, which kept distinct in prehistoric times, have now been blended and confounded together, and even the humped cattle of India have been crossed with our domestic varieties and have produced fertile offspring. Two species of wild pig, as before stated, the European *Sus scrofa* and the *Sus Indica*, have also been confounded together in some of our domestic races. Yet there is every reason to believe that such mixtures would not have occurred in a state of nature. This may be explained simply by the preference which animals exhibit to unite with others of the same race rather than with those which differ considerably from them.

In Paraguay the horses have much freedom, and those of the native race of the same colour and size prefer associating together rather than with imported horses. Three distinct sub-races of the horse in Circassia, whilst living nearly a free life, refrain almost always from crossing. It has been observed, in a district stocked with heavy Lincolnshire and light Norfolk sheep, that both kinds will, when they are all turned out together, 'in a very short time separate to a sheep;' the Lincolnshires drawing off to the rich soil, and the Norfolks to their own dry light soil; and as long as there is plenty of grass, 'the two breeds keep themselves as distinct as rooks and pigeons. In this case different habits of life tend to keep the races distinct.'†

The origin of a new race of sheep, recorded in the Philosophical Transactions for 1813, also illustrates the disposition of even closely related varieties to herd apart, and has also been cited by Professor Huxley as proving the strong

* Origin of Species, 4th edition, p. 300.

† Darwin 'On Variation,' chap. xvi. p. 102, who cites Marshall.

tendency which there is in a newly arisen variety to be perpetuated. 'A farmer in Massachusetts possessed a flock of fifteen ewes and a ram of the ordinary kind. In the year 1791 one of the ewes presented her owner with a male lamb, differing from its parents by a proportionally long body and short bandy legs, whence it was unable to emulate its relatives in those sportive leaps over the neighbouring fences, in which they were in the habit of indulging much to the good farmer's vexation. His neighbours imagined that it would be an excellent thing if all his sheep were endued with the stay-at-home tendencies enforced by nature upon the newly arrived ram, and they advised Wright to kill the old patriarch of his fold and instal the "otter," or "Ancon" ram in his place. The result justified their sagacious anticipations. Young lambs were almost always pure Ancons or pure ordinary sheep, and when sufficient Ancon sheep were obtained to interbreed with one another, it was found that the offspring was always pure Ancon. In this well-authenticated instance we have a distinct race established at once or by a leap, and that race breeding true. When the Ancon sheep were herded with other sheep they kept together, so that it was believed that this breed might have been indefinitely protracted, had it not been superseded by the introduction of the Merino sheep, which were not only superior to the Ancons in wool and meat, but were equally quiet and orderly.'*

Pallas on domesticity eliminating sterility. Correlation of growth.—Pallas has remarked that domesticity eliminates the tendency to sterility which belongs to nearly allied species in a state of nature. As bearing on this subject, Mr. Darwin observes that there are many animals which, when tamed or subjugated to man, refuse to breed in captivity although they enjoy perfect health, as the tiger, for example, in India, and parrots in Europe, and the elephant except when allowed, as in Assam, to range in a half-wild state in the woods; a fact showing how easily sterility may be superinduced when habits long fixed, as well as many of the

* Huxley, Westminster Review, 1860. Article on Darwin 'On the Origin of Species.'

conditions of existence in a wild state, are interfered with. But those species which more readily accommodate themselves to new circumstances arising out of their association with man, and which can be carried by him to all climates, exhibit the same plasticity of character in reference to the reproductive organs.

It cannot, however, be pretended that a satisfactory explanation can be offered of the tendency of domestication to increase the prolificness of animals and plants. In reference to the opposite effect of a return to the wild state, the following fact is worthy of mention. About the year 1419 some rabbits were introduced into Porto Santo, one of the Madeira islands, where they multiplied exceedingly, and have flourished ever since in a feral state. In many of their characters they constitute a marked race, which is smaller than the original parent stock. When two of the males were brought to the London Zoological Gardens, they refused to pair with any varieties of domestic rabbits, isolation for many generations under peculiar geographical conditions having apparently superinduced an aversion to cross even with such nearly allied races.

If two wild species, such as the wolf and the jackal, can by the intervention of man be made to breed together and the offspring proves fertile, such a result must shake our faith in the theory that species have been specially endowed with mutual sterility in order to keep them distinct. It is certainly very strange that when domesticated races have been made to differ to such an extent that if wild they would have been referred by naturalists to different genera, there should still be scarcely any well-attested examples even of an approach to sterility in their mongrel offspring. It is all the more strange if we are persuaded of the truth of Mr. Darwin's view, that the whole organisation of an animal is so tied together, that when even slight variations occur in any one part other parts usually become modified.

Among many other illustrations which he gives of this principle, called by him in the 'Origin of Species' 'correlation of growth,' and in his last work 'correlated variability,' he mentions that pigeons with feathered feet have skin

between their outer toes, pigeons with short beaks have small feet, and those with long beaks large feet; and some instances of correlation, he remarks, are quite whimsical: thus, cats which are entirely white and have blue eyes are generally deaf. One case is recorded where the blue iris at the end of four months began to grow dark-coloured, and then the cat began to hear.*

If the sterility of the mule offspring be due, as the same naturalist suggests, to the imperfection of their reproductive organs arising from the blending together of two different structures and constitutions, which causes a disturbance and interferes with the development of the embryo, we might have expected that differences affecting permanently not only the external form and shape, but even the shape of the skull in many vertebrate animals, as well as their instincts and habits, would have been accompanied, when such fixed varieties were crossed, with a disturbance in the reproductive organs and consequent sterility in the hybrids.

At the same time we must remember that the greatest changes in races have been brought about by selection, and it has never been the object of man to modify the reproductive organs with a view of producing two races mutually sterile, nor, if he wished to make such an experiment, would he know in what manner to proceed. Moreover, we have seen how possible it is to alter the foliage of plants without their seeds varying, or to change their seeds, fruit, or flowers without the character of the root or leaves being affected. It is in fact established, in spite of 'correlation,' that we may cause some organs to be greatly modified, while another to which we have not directed our attention may continue almost or entirely unaltered. In the next chapter, when we treat of Natural Selection, we shall have again to consider in what way the varieties of wild species may be supposed to have departed so far in the course of ages from the parent stock and from each other as to be incapable of being crossed, notwithstanding the fact which seems directly opposed to such a result, that a slight amount of variation in individuals of the same species when they are intermarried infuses fresh vigour and increased fertility into the offspring.

* Dr. Sichet, cited by Darwin 'On Variation,' p. 329.

CHAPTER XXXVII.

NATURAL SELECTION.

NATURAL AS COMPARED TO ARTIFICIAL SELECTION—TENDENCY IN EACH SPECIES TO MULTIPLY BEYOND THE MEANS OF SUBSISTENCE—TERMS 'SELECTION' AND 'SURVIVAL OF THE FITTEST'—GREAT NUMBER AND VARIETY OF THE NATURAL CONDITIONS OF EXISTENCE ON WHICH THE CONSTANCY OR VARIATION OF A SPECIES DEPENDS—ACCLIMATISATION OF SPECIES—THE INTERCROSSING OF SLIGHT VARIETIES BENEFICIAL—BREEDING IN AND IN INJURIOUS—WILD HYBRID PLANTS, AND OPINIONS OF LINNÆUS ON PROTEAN GENERA—DE CANDOLLE ON WILD HYBRIDS—HYBRIDITY WILL NOT ACCOUNT FOR SPECIAL INSTINCTS—THE SPECIES OF POLYMORPHOUS GENERA MORE VARIABLE AND COMPARATIVELY MODERN—ALTERNATE GENERATION DOES NOT EXPLAIN THE ORIGIN OF NEW SPECIES.

NATURAL AS COMPARED TO ARTIFICIAL SELECTION.—In the last chapter we have spoken of the great changes which man has brought about in the course of many generations in the form and characters of animals and plants, by selecting certain useful varieties of a species, and breeding from them to the exclusion of other varieties less profitable or pleasing to him. In this way he has gone on accumulating differences in successive generations until new races have been formed as distinct in outward shape, and sometimes in the internal structure of important organs, as are most of the species which we meet with in nature; the races, however, thus artificially produced being distinguishable from wild species by the fertility of the offspring produced by their union.

We may next consider the modification of species effected by variation and what Mr. Darwin has called 'natural selection,' of which we gave a brief analysis in Chap. XXXV. How far do the breeder, the agriculturist, and gardener, when they form new races, simply imitate a process by which, in a much greater lapse of time, nature causes still more important deviations from the original type?

Of the laws which may govern variation we are, as Mr. Darwin admits, profoundly ignorant; and if, as seems probable, these laws embrace the principle of progressive development explained in the first volume (Chap. IX.), they must be of so high and transcendental a nature that we may well despair of ever gaining more than a dim insight into them. But granting what is undeniable, that there is a tendency in all animals and plants to possess individual peculiarities by which they differ slightly from their parents and from each other, are there not forces in operation in the organic and inorganic world, which, in the course of thousands or millions of generations, may cause new races, varying more and more in a particular direction, until at length they constitute new species? If there be such a process in nature, it will most nearly resemble that kind of human selection which has been called 'unconscious,' and which for reasons explained in the last chapter is even more effective in the long run than that which is intentional.

Tendency in each species to multiply beyond the means of subsistence.—It has already been stated that if all the progeny of each animal and plant which are born into the world were allowed to come to maturity, a single species would soon fill the whole of the habitable land or water. Malthus long ago pointed out, that in the case of man, if his capability of increase were not checked by scarcity of food, the earth would soon fail to afford standing-room for the descendants of a single pair. The elephant, says Darwin, although reckoned the slowest breeder of all known animals, would nevertheless so multiply, if we assume that it only begins to have young when thirty years old, and brings forth three pair between that age and the age of ninety, that if all its descendants were to live out the term of their natural life, at the end of five centuries there would be fifteen million elephants descended from a single pair.

In the severe struggle for existence which is always going on, those varieties or species which have any even the slightest advantage over others inhabiting the same district will be the survivors. They may be able to bear a degree of cold or heat, moisture or dryness, which others cannot endure; they

may have strength or agility to escape foes to which others must fall victims; but the great trial, as before hinted, consists in the capacity of maintaining their ground at that season of the year when food is scarcest.

'Natural Selection' or 'Survival of the fittest.'—Mr. Herbert Spencer has proposed to substitute for 'Natural Selection' the term 'Survival of the fittest;'* an expression which is often very appropriate, and which some naturalists prefer, because the various causes which in the natural world enable one variety or race to prevail over another, act according to fixed laws, and do not imply a conscious choice like the selection of the breeder. But the metaphor employed by Darwin appears to me legitimate and often useful, as reminding us of the close analogy which exists between the manner in which new races are formed by man and the way in which it is supposed by Darwin and Wallace that they are slowly produced by nature. Professor Huxley in his comments on this subject observes, that the winds and waves of the Bay of Biscay in the district called the Landes near Bordeaux have spread out over a wide area great heaps of sand all the grains of which are below a certain size. These grains have been separated from the larger gravel with as much precision as if by the aid of a sieve. That which the wind and the sea are to a sandy beach the sum of all the influences which we term the conditions of existence is to living organisms. The weak are sifted out from the strong. A frosty night selects the hardy plants in a plantation from among the tender ones as effectually as if the intelligence of a gardener had been operative in cutting the weaker organisms down.†

If the reader will reflect on the changes in the earth's physical geography and climate which were alluded to in the first volume (Chapters XI. and XII.), as having occurred in the course of geological periods, he will not fail to perceive that the new conditions to which plants and animals inhabiting any given province must be exposed will be far more important in the aggregate than the change of circumstances to

* Principles of Biology, p. 444.

† Nat. Hist. Rev., Vol. IV., p. 578, 'On Origin of Species.

which man can in a few thousand years subject any animal or plant under domestication.

Were we to attempt to enumerate all the conditions which Mr. Herbert Spencer has concisely termed the 'environment' of a species, they would be almost endless. They would comprise not only the mean temperature of the air or water, but the extreme heat or cold in the different seasons of the year, the quantity and intensity of sunshine at different periods, the number of clear and of rainy days, the quantity of ice and snow, the direction and strength of the wind, the pressure of the atmosphere and its electrical state, the nature of the soil, its elevation above the sea, the habits, instincts, and properties of hundreds of contemporary animals and plants, some of them friendly, others inimical, the comparative abundance or rarity of those species on which the food of a given animal or plant may depend—circumstances, many of them, wholly beyond the control of the breeder or horticulturist. All of them, moreover, are brought into play by natural selection with a uniformity and persistency which man cannot emulate.

Dr. Hooker ascertained that the average range in vertical height of flowering plants in the Himalayan mountains amounted to 4,000 feet, and the upper and lower limits of some species are even distant from each other as much as 8,000 feet. If we transplant individuals which inhabit the higher limits in these mountains into our British gardens, we find that they are hardier, and better able to stand the cooler climate of England, than those taken from the inferior or warmer stations. This acclimatisation has been the result of natural selection during thousands of generations. The physiological constitution of the plant has been acted upon, and a hardy race established, although the change may not have been sufficient to cause it to rank as more than a variety. It may sometimes be more dwarfed in size than individuals of the same species living in the moist and hotter region far below. It may perhaps vary slightly in the colour of its flowers, and, if deciduous, in the period of shedding its leaves or in its general habits of growth. Yet its characters may not be on the whole sufficiently distinct to induce the botanist to rank it as

more than what is called a geographical variety. In arriving at such an opinion he may perhaps be chiefly guided by his ability to trace in the individuals inhabiting all the intermediate heights a gradual passage from one extreme of the series to another.

Intercrossing of slight varieties beneficial.—It would be an interesting experiment, and one which has not yet been made, to cross individuals taken from the lowest station with those hardier races which have been formed by acclimatisation in the upper regions of the mountain, and ascertain whether they would produce as much seed as individuals fertilised by the pollen of plants of the same station. If there were any signs of comparative sterility in such crosses, it would afford an indication of the commencement under nature of that character which distinguishes wild species from artificially formed races. There is good reason, however, to believe that before any difficulty of crossing, or any deficiency of prolific power in the offspring, would be apparent, the races must depart so widely from each other that their distinctness as species would already be a debateable question with the naturalist. And this brings us to the principal obstacle which we encounter when we endeavour to refer the gradual formation of a new species to variation and natural selection. If some degree of sterility was found in the offspring of slight varieties, and this want of prolific power went on augmenting in proportion as the deviation from a common stock became more and more marked, the fact that closely allied species inhabiting the same region keep distinct would be intelligible. But the phenomena are precisely the reverse. Instead of any reluctance being exhibited by slight variations to intermarry and propagate their kind, their intermixture, on the contrary, takes place freely and infuses fresh vigour and fertility into the species. Individuals of the normal type are always the most numerous, and slight varieties are usually soon merged in the general average, so that the new characters disappear. In some cases where the races are so wide apart as to be thought by some to belong to distinct species, it is only necessary to cross their mongrel or hybrid offspring with pure individuals of one of

the two parent stocks for six or sometimes eight generations in succession, and every trace of the foreign admixture will be lost. The mutual absorption in this manner of the European and negro races the one into the other, by a certain number of intermarriages with one of the two stocks, has been frequently verified. The efficacy of the principle above adverted to, in causing species to breed true for ages, and checking lawless divergence, in spite of the numerous varieties which occur in every generation, is obvious; the only difficulty is to conceive how, if there be such proneness in each aberrant form to merge into the normal type, a new and permanent species can ever be established. It would seem to require prolonged isolation under altered conditions, such as may occur in different parts of the same continent, or still more frequently in different islands of the same archipelago. But we have yet to learn what degree of divergence must be attained in two races sprung from the same stock before a decided disinclination to breed together will arise, and how much farther this must be carried before the offspring of the cross, if produced, will be sterile.

Breeding in and in injurious.—It has already been stated that certain domestic races prefer breeding with their own kind; while on the other hand, it is well ascertained that too much breeding in and in has an injurious effect.

The half-wild cattle which have been kept for four or five centuries or more in British parks, as in those of Lord Tankerville and the Duke of Hamilton, where the total number varies from sixty to eighty, are relatively far less fertile than the enormous herds of half-wild cattle in South America. But even in the latter case it is believed that the occasional introduction of animals from distant localities is necessary to prevent degeneration in size and fertility.* The decrease in bulk from ancient times of the British cattle alluded to must, says Darwin, have been prodigious, as according to Rütimeyer they are the descendants of the gigantic *Bos primigenius*. The Chillingham cattle are white, but this is partly due to selection, as dark-coloured calves are

* Darwin 'On Variation,' chap. xvii., who cites Azara.

occasionally destroyed. In the Pampas, in Texas, or in Africa, where cattle have run wild in large herds, they have acquired a nearly uniform dark brownish-red.* A breed called Niatas, seen by Darwin on the banks of the Plata, has a short and broad forehead and other peculiarities in the shape of the skull and in the projection and curvature of the lower jaw. In this variety scarcely a single bone agrees exactly in shape with that of the common ox. This breed, which has existed for at least a century, is a good illustration of the manner in which a marked variety may be formed in a nearly wild state, and of the tendency of such a new race, when brought into contact with other breeds, to keep distinct. Such a tendency may point to the manner in which, in the course of many generations, if man did not interfere, a greater divergence from a common original and a more decided aversion to sexual union might be superinduced. If the lapse of time necessary for such transformations be very great, the extinction of intermediate races will take place, by which a new bar to the commingling of the nearest allied types will be raised.

In speculating on this subject, Mr. Darwin reminds us that a slight change in the conditions of life is found to be very generally advantageous to cultivated animals and plants, although we know that great changes are sometimes injurious. So, in the case of man, the invalid whose constitution will be benefited by going from England to the South of France or Madeira, may perish if transferred to Fernando Po. We may easily imagine, that, although the crossing of most of the varieties of cultivated plants and animals imparts strength and fertility to them, yet under nature, and in the course of ages, the variation may be carried so far as to modify the reproductive organs, and render the formation of a fertile hybrid germ impossible.†

The refusal of many tamed animals to breed in captivity, has been alluded to, and it demonstrates the susceptibility of the reproductive system to be affected by a change in

* Azara and others, cited by Darwin 'On Variation,' p. 86.

† Darwin 'On Variation,' chap. xviii.

the natural conditions of life. That changes greater in degree or even equal, but continuing uniformly in force for many thousands of generations, should bring about the mutual sterility of two allied races or species, is quite conceivable.

If this point of divergence had been reached by the breeder or horticulturist, the derivability of a new species by gradual deviation from an old type would almost have ceased to be a debateable question in natural history; but perhaps the tendency of varieties to keep separate is as much as we could expect to see produced in the limited time over which our observations can have extended, more especially if (as is believed by some naturalists) domestication has itself a tendency to eliminate sterility.

Allusion has been made to the extinction of intermediate varieties. This would happen the more readily on the principle well pointed out by Darwin, that in order that a given area should support the greatest number of individuals, these ought to belong to a great many widely dissimilar types; and what is true of genera, must sometimes be true of the races of a species. There may be room for those which represent the extreme terms of a series, and no equally advantageous place for those of intermediate characters.

Wild hybrid plants, and opinions of Linnæus on protean genera.—If wild species were not averse to intermarry, or if their hybrid offspring were not almost always sterile, it is obvious that in a few generations there would be a blending together of all existing types, and we should behold everywhere that state of confusion which we now only meet with in certain exceptional cases.

To the occasional occurrence of protean or polymorphous genera, as they have sometimes been called, where a great number of closely allied species occur, Linnæus makes frequent allusion in his writings. He was evidently unable to reconcile the phenomenon with his dogma of the immutability of primordially created species. In an address to the University of Upsala in 1751,* he gave a list of nearly thirty 'prolific' genera of plants, in which the species

* Linnæus, 'Plantæ Hybridæ,' 32nd Dissertation of the Amœnitates Academicæ, vol. iii. pp. 28–62.

were of doubtful or suspicious value; enumerating, among others, the willows and saxifrages in Europe, the oaks and asters in North America, the cactuses in South America, the heaths and everlastings at the Cape; in each of which there were so many intermediate gradations between what are commonly called allied species, as to make their origin a curious subject of enquiry. He considered how far hybridisation could explain the enigma, and having his new discovery of the sexuality of plants uppermost in his mind, he was disposed to exaggerate the extent to which that cause might have been efficacious in originating new forms. Hybrids, he says, are not always sterile, and not only species, but even genera, may have arisen from this source.* But in a great many instances, when he speaks of one species being derived from an older one, and when he calls allied species, which inhabit distant countries, 'sisters,' as being of common origin, and when he remarks of several forms that they had their first origin from one and the same source, he is evidently speculating on the origin of species by variation. In this spirit he avowedly groups many forms of *Ophrys*, *Valerianella*, *Myosotis*, *Medicago*, and other genera under single collective specific names, because, he says, after a comparison of a great number of them, all the forms will be seen to have had their origin from one source. He even throws out the idea that the day may come when botanists may hold that all the species of the same genus may have sprung from the same mother.†

The occurrence in a state of nature of some hybrids, although rare, is admitted by all botanists. *Centaurea hybrida* is produced, according to Herbert, by the frequent intermixture of two well-known species of Centaurea; but this hybrid race never seeds. *Ranunculus lacerus*, also sterile, has been produced accidentally at Grenoble, and near Paris, by the union of two ranunculi; but this occurred in gardens.‡

* 'Novas species, immo et genera ex copulâ diversarum specierum in Regno Vegetabili oriri,' etc.—Amœn. Academ. orig. ed. 1744, ed. Holm. 1749, vol. i. p. 70.

† 'Tot species dici congeneres quot eadem matre sint progenitæ.'—Amœnitates Academicæ, vol. vi. p. 12. Two eminent Swedish naturalists, Professors Fries and Lovén, have kindly pointed out to me these and many other passages in which Linnæus shows that he had freely speculated on the variability and transmutation of species.

‡ Hon. and Rev. W. Herbert, Hort. Trans., vol. iv. p. 41.

Mr. Darwin has lately (in the summer of 1867) satisfied himself by experiment that the common oxlip is a natural hybrid between the primrose and cowslip, and these two last he considers to be distinct species. Mr. Herbert, in one of his ingenious papers on mule plants, endeavours to account for their rare occurrence in a state of nature, from the circumstance that all the combinations that were likely to occur have already been made many centuries ago; but in our gardens, he says, whenever species, having a certain degree of affinity to each other, are transported from different countries, and brought for the first time into contact, they give rise to hybrid species.*

De Candolle's opinions.—Auguste De Candolle, in his Essay on Botanical Geography, published in 1820, observes, that the *varieties* of plants range themselves under two general heads: those produced by external circumstances, and those formed by hybridity. After adducing various arguments to show that neither of these causes can explain the permanent diversity of plants indigenous in different regions, he says, in regard to the crossing of races, 'I can perfectly comprehend, without altogether sharing the opinion, that, where many species of the same genera occur near together, hybrid species may be formed, and I am aware that the great number of species of certain genera which are found in particular regions may be explained in this manner; but I am unable to conceive how any one can regard the same explanation as applicable to species which live naturally at great distances. If the three larches, for example, now known in the world, lived in the same localities, I might then believe that one of them was the produce of the crossing of the two others; but I never could admit that the Siberian species has been produced by the crossing of those of Europe and America. I see, then, that there exist, in organised beings, permanent differences which cannot be referred to any one of the actual causes of variation, and these differences are what constitute species.' † In this passage De Candolle assumes that the actual causes of variation have their strict and definite limits; an hypothesis

* Hon. and Rev. W. Herbert, Hort. Trans., vol. iv. p. 41.

† Essai Elémentaire, &c. 3ième partie.

which the advocates of transmutation say, and not without reason, is quite as arbitrary as the opposite or rival assumption of indefinite modifiability.

Hybridity will not account for special instincts.—As to the derivation of species in general from the mixture of a limited number of original stocks, differing widely from each other, all our experience is against such an hypothesis; for between plants or animals of very distinct genera we can obtain no cross-breeds. Nor is it easy to comprehend how species of intermediate character between two divergent types could give rise to a mongrel offspring having qualities and instincts fitting them to hold their ground in the struggle for life.

If we take some genus of insects, such as the bee, we find that each of the numerous species has some difference in its habits, its mode of collecting honey, or constructing its dwelling, or providing for its young, and other particulars. In the case of the common hive bee, the workers are described, by Kirby and Spence, as being endowed with no less than thirty distinct instincts.* So also we find that, amongst a most numerous class of spiders, there are nearly as many different modes of spinning their webs as there are species. When we recollect how complicated are the relations of these instincts with co-existing species, both of the animal and vegetable kingdoms, it is scarcely possible to imagine that a bastard race could spring from the union of these species, and retain just so much of the qualities of each parent stock as to preserve its ground in spite of the dangers which surround it.

The theory of the origin of species by variation and natural selection would be untenable, unless we could assign very different degrees of antiquity to the generic and specific types now existing. Some of them must date from remote geological periods, others must be comparatively modern. Of this last class are those forms of which the living representatives run so much the one into the other that scarcely any two naturalists can agree as to where the lines

* Intr. to Entom. vol. ii. p. 504, ed. 1817.

of demarcation between the species ought to be drawn. The British roses present a familiar illustration of this ambiguous state of things, Mr. Bentham making only five species of them, and Dr. Babington seventeen. Mr. Darwin sees in this abundance of closely allied species an active manufacture of new races, and a want of time since their origin to bring about the extinction of the varieties which still link together the divergent members of the series, and he remarks that the species of these polymorphous genera are unusually variable. When the reader has reflected on what will be said in Chapter XLII. on the extinction of species, he will understand why, as a general rule, there are so many missing links, and why 'protean' genera are the exception. No clue to this enigma is afforded by the hypothesis of special creation. On the other hand, if it had been found that fertile hybrids could spring from animals and plants which are remote in their organisation, the occurrence of protean genera might certainly be explained; but in that case they ought to have been universal, and the present condition of the animal and vegetable world would then be a greater mystery than ever.

Sexual selection.—A considerable number of the most striking external characters of animals are confined to one sex, such as the horns and canine tusks often found in the males only of quadrupeds, the ornamental plumes, gay colours, and musical voices of male birds, and the varied horns and excrescences of male insects. Mr. Darwin has shown that these characters are often useful to the males in their struggle for mates. Some actually fight together, and the possessor of the greatest strength and the best weapons will be the parent of the next generation; others captivate the females by their beauty or their song, and these, by obtaining the earliest and most vigorous mates, will have the most numerous and most healthy offspring. Favoured individuals will thus have an advantage in the transmission of their peculiarities; and in this manner, Mr. Darwin believes, have been produced the noble antlers of the stag, the sharp spurs of the cock, and the gorgeous train of the bird of Paradise. Sexual selection thus becomes an important supplement to

natural selection, and may enable us to account for structures which could not be explained by the mere 'preservation of favourable variations in the struggle for life.'

Alternate generation.—The discovery in certain classes of invertebrate animals of what has been called 'alternate generation,' has suggested to some zoologists a possible mode by which Nature may usher abruptly into the world not only new organisms but even types of being of a higher grade than any which pre-existed in the same class. Certain sertularian polyps give birth to other polyps like themselves, and these again produce other individuals of the same form and structure, and this may continue for many generations till at last one of the series gives birth to a more highly organised creature called a Medusa. Formerly naturalists regarded this Medusa as belonging to a distinct genus or even family, of decidedly higher or more complex organisation than the Sertulariæ. If then, it is said, under a change of conditions the Sertularia and the Medusa should each of them go on for an indefinite number of generations producing, according to the ordinary rules of inheritance, offspring like themselves, we should have an example of the coming into existence of a new and higher form without the disappearance of the lower one from which it had been evolved; but, unfortunately for such speculations, nothing of the kind has ever been witnessed. The Sertularia, although it is hatched from an egg, never produces one, but simply gives birth to other polyps by what is termed internal gemmation, and when at length the male and female Medusæ, after sexual union, produce eggs from which the Sertulariæ are born, the whole cycle of changes returns into itself, just as do the metamorphoses of an insect. The same may be said of certain aphides, which, coming from an egg, give birth by gemmation to asexual offspring, and these again to others like themselves, till at length some of their descendants produce perfect and winged males and females, from whose union eggs proceed, and then the cycle of transformation recommences.

Even if there had been any indication of the Sertularia and Medusa becoming each of them independent of the

other, this phenomenon would not afford an illustration of what is usually meant by special creation, as the new form would still be evolved out of the older one by descent. In truth there are only as yet two rival hypotheses, between which we have our choice in regard to the origin of species —namely, first, that of special creation—and, secondly, that of creation by variation and natural selection. In the next four chapters I shall treat of the light thrown by the geographical distribution of animals and plants on the claims of these two rival hypotheses to our acceptance.

CHAPTER XXXVIII.

ON THE GEOGRAPHICAL DISTRIBUTION OF SPECIES.

GEOGRAPHICAL DISTRIBUTION OF ANIMALS—BUFFON ON SPECIFIC DISTINCTNESS OF QUADRUPEDS OF THE OLD AND NEW WORLDS—DOCTRINE OF 'NATURAL BARRIERS'—AUSTRALIAN MARSUPIALS—GEOGRAPHICAL RELATION OF EXTINCT FOSSIL FORMS TO THEIR NEAREST ALLIED LIVING GENERA AND SPECIES—GEOGRAPHICAL PROVINCES OF BIRDS ACCORDING TO DR. SCLATER—THEIR APPLICABILITY TO ANIMALS AND PLANTS GENERALLY—NEOTROPICAL REGION—NEOARCTIC—PALÆARCTIC—ETHIOPIAN—INDIAN—AUSTRALIAN—WALLACE ON THE LIMITS OF THE INDIAN AND AUSTRALIAN REGIONS IN THE MALAY ARCHIPELAGO.

Geographical Distribution of Animals.—Although in speculating on 'philosophical possibilities,' said Buffon, writing in 1755, 'the same temperature might have been expected, all other circumstances being equal, to produce the same beings in different parts of the globe, both in the animal and vegetable kingdoms, yet it is an undoubted fact, that when America was discovered, its indigenous quadrupeds were all dissimilar to those previously known in the Old World. The elephant, the rhinoceros, the hippopotamus, the camelopard, the camel, the dromedary, the buffalo, the horse, the ass, the lion, the tiger, the apes, the baboons, and a number of other mammalia, were nowhere to be met with on the new continent; while in the old, the American species, of the same great class, were nowhere to be seen—the tapir, the lama, the pecari, the jaguar, the couguar, the agouti, the paca, the coati, and the sloth.'

These phenomena, although few in number relatively to the whole animate creation, were so striking and so positive in their nature, that the great French naturalist caught sight at once of a general law in the geographical distribution of organic beings, namely, the limitation of groups of distinct species to regions separated from the rest of the globe by certain natural barriers. It was, therefore, in a truly philo-

sophical spirit that, relying on the clearness of the evidence obtained respecting the larger quadrupeds, he ventured to call in question the identifications announced by some contemporary naturalists of species of animals said to be common to the southern extremities of America and Africa.*

In order to appreciate the importance and novelty of the doctrine, that separate areas of land and water were the abodes of distinct species of animals and plants, we must look back to the times of Buffon, and see in what crude conjectures even so great a naturalist as his illustrious contemporary Linnæus indulged, when speculating on the manner in which the earth may first have become peopled with its present inhabitants. The habitable world was imagined by the Swedish philosopher to have been for a certain time limited to one small tract, the only portion of the earth's surface that was as yet laid bare by the subsidence of the primæval ocean. In this fertile spot the originals of all the species of plants which exist on this globe were congregated together with the first ancestors of all animals and of the human race. 'In quâ commodè habitaverint animalia omnia, et vegetabilia lætè germinaverint.' In order to accommodate the various habits of so many creatures, and to provide a diversity of climate suited to their several natures, the tract in which the creation took place was supposed to have been situated in some warm region of the earth, but to have contained a lofty mountain range, on the heights and in the declivities of which were to be found all temperatures and every climate, from that of the torrid to that of the frozen zone.† There are still perhaps some geologists who adhere to a notion once very popular, that there are signs of a universal ocean at a remote period after the planet had become the abode of living creatures. But few will now deny that the proportion of sea and land approached very nearly to that now established long before the present species of plants and animals had come into being.

The reader must bear in mind that the language of Buffon,

* Buffon, vol. v. 1755.—On the Virginian Opossum.

† 'De terrâ habitabili incremento;' also Prichard, Phys. Hist. of Mankind, vol. i. p. 17, where the hypotheses of different naturalists are enumerated.

in 1755, respecting 'natural barriers' which has since been so popular, would be wholly without meaning had not the geographical distribution of organic beings led naturalists to adopt very generally the doctrine of specific centres, or, in other words, to believe that each species, whether of plant or animal, originated in a single birthplace. Reject this view, and the fact that not a single native quadruped is common to Australia, the Cape of Good Hope, and South America, can in no way be explained by adverting to the wide extent of intervening ocean, or to the sterile deserts, or the great heat or cold of the climates, through which each species must have passed, before it could migrate from one of those distant regions to another. It might fairly be asked of one who talked of impassable barriers, why the same kangaroos, rhinoceroses, or lamas, should not have been created simultaneously in Australia, Africa, and South America? The horse, the ox, and the dog, although foreign to these countries until introduced by man, are now able to support themselves there in a wild state; and we can scarcely doubt that many of the quadrupeds at present peculiar to Australia, Africa, and South America, might have continued in like manner to inhabit all the three continents, had they been indigenous in each, or could they once have got a footing there as new colonists.

We have seen in the passage already cited that Buffon called attention to the fact that the apes and baboons of the Old World were nowhere to be found in America. Now that so many new forms of quadrumana have been brought to light in both continents, the want of agreement in the anatomical and many other characters of the two groups has been rendered even still more prominent.

The Old-World apes and monkeys have been called Catarrhini because they have a narrow division between the nostrils; those of the New World, Platyrrhini because their nostrils are widely separated. In the Catarrhine division the number of teeth, not only in the Orangs and Gibbons which approach nearest to the human race in form and structure, but in all the other quadrumana with the exception of one or two aberrant groups such as the Lemurs, are 32, as

in man, whereas in all the Platyrrhine monkeys they are 36, for they have four additional false molars. This marked distinction in their dentition is accompanied by many other differences; such as the prehensile tails belonging exclusively to so many of the American monkeys, and the cheek-pouches peculiar to the Old-World quadrumana.

Australian marsupials.—The adherence to certain peculiar types of structure observable in the animals inhabiting distinct geographical provinces was illustrated in a still more striking manner, some time after the publication of Buffon's great work, by the discovery in Australia of a group of mammalia so unlike those of the Old World as to be referable even to a distinct sub-class called the Marsupial, of which there was only one genus previously known on the globe, namely, the Opossum (*Didelphis*) of America. Some of these pouched animals, like the kangaroo, were herbivorous, others, like the Tasmanian wolf (*Thylacinus*), carnivorous, and on the whole they presented a parallel series in which were found representatives of nearly all the grand divisions of the placental mammalia of the rest of the world. Mr. Waterhouse has described about 140 species proper to the mainland of Australia, and about 9 others inhabiting New Guinea and some neighbouring islands of the Malay Archipelago. Among these, only one species, the flying opossum (*Petaurus ariel*), is common to one of the islands and the continent.

Geographical relation of extinct fossil forms to the nearest allied living genera and species.—When we speculate on the meaning of this restriction of a peculiar division of the vertebrata to a single province of the land, and try, by aid of it, to gain some insight as to the plan which Nature has followed in peopling the earth with new species, we find ourselves in some degree precluded from attributing the peculiarity of the fauna to the nature of the climate, soil, and vegetation of Australia. It has at least been ascertained experimentally that when placental mammalia of various orders, whether herbivorous or carnivorous—such as the ox, the horse, the dog, and the cat—run wild in Australia, they are not only a match for the native animals, but often obtain a mastery over them and multiply greatly at their expense. How, then, does

it happen that the marsupials ever became dominant and gained so complete an ascendancy over the placentals in the struggle for life? The answer seems to be, that the more highly organised placentals were never able to gain access to Australia since it emerged from beneath the sea. It is certain that the marsupial fauna of that continent is of great antiquity, for when we examine the bone-caves and superficial alluvium of that part of the world, we find in them, as in formations of corresponding age in Europe, the remains of extinct quadrupeds; but, instead of being referable to the placental class, as in the Old World, the Australian fossils consist of lost species of kangaroo, wombat, thylacine, and other marsupials. One of these, the *Diprotodon* of Owen, allied to the kangaroo, is of the size of a large rhinoceros; another, *Nototherium* of Owen, not much inferior in bulk. They are associated with extinct species of *Dasyurus*, besides many of smaller dimensions, such as Phalangers and Potoroos.

In like manner, when we turn to the geological records of South America, we find among the fossil remains of an age immediately antecedent to the present, entombed in cavern and alluvial deposits, the skeletons of Megatherium, Megalonyx, Glyptodon, Mylodon, Toxodon, and Macrauchenia, extinct forms generically allied to the existing sloth, armadillo, cavy, capybara, and lama. In the caves also of Brazil we meet with extinct monkeys associated with the above, and they are referable to the genera Cebus and Callithrix, both belonging to the Platyrrhine or New-World type of quadrumana before mentioned. Thirdly, if we turn to the Europæo-Asiatic and African province—a region which comprises Europe, Asia, and the north of Africa—geology teaches us, in like manner, that where the rein-deer, musk-ox, elephant, rhinoceros, hippopotamus, horse, and many other Old-World types now prevail, there also extinct species of the same genera abounded formerly at a very modern geological period. In the present state of science we cannot speak of the fossil quadrumana of the same great province, because the Pliocene mammalia of tropical regions have as yet been so imperfectly investigated, and it is only within the tropics that the ape and monkey tribe is at present met

with. But it is worthy of notice that the extinct fossil monkeys which have been discovered in Europe and India, all of them of Miocene age, are referable to Old-World forms or to the Catarrhine division, such as the Semnopithecus and the Gibbons.

Professor Owen and Mr. Darwin have dwelt emphatically on this manifest relationship between the living and the dead—between peculiar genera and families of mammalia now inhabiting certain parts of the world and the fossil representatives of the same families found in corresponding regions.*

No hypothesis, therefore, respecting the origin of species will be satisfactory which does not render some account of the two classes of phenomena already alluded to in this chapter. First, species, and often genera and still larger groups, have such a range in space as implies that they have spread in all directions from a limited area called a 'centre of creation,' until their progress was stopped by some natural barriers, or conditions in the organic and inorganic world, hostile to their farther extension. Secondly, the restriction of peculiar generic forms to certain parts of the globe is not confined to the present period, but may be traced back to an antecedent geological epoch, when most of the species of mammalia were different from those now living. The significance of this last-mentioned fact can hardly be overrated. If we find Latin inscriptions of ancient date most common in the country where Italian is now spoken, Greek inscriptions most abundant where they now talk modern Greek, and Egyptian hieroglyphics inscribed on ancient monuments where for centuries after the Christian era the kindred Coptic tongue was still in use, we recognise at once that there is a geographical connection between the three dead and the three living or modern languages, which, even if the entire intervening history of those countries were lost, could not be questioned. In this case it would afford a powerful argument in favour of the derivative origin of the three modern languages, each of them having a nearer relationship to one of the extinct tongues than to any other lost

* Owen, British Mammals and Birds; and Darwin, Journal of South America.

forms of speech known to us by tradition or history as having been used elsewhere on the globe. So the intimate connection between the geographical distribution of the fossil and recent forms of mammalia points to the theory (without absolutely demonstrating its truth) that the existing species of animals and plants, like the above-mentioned modern forms of speech, are of derivative origin and not primordial or independent creations.

Geographical provinces of animals.—It has been ascertained that the sea as well as the land may be divided into what have been called distinct provinces, each inhabited by certain species of animals and plants, there being a considerable coincidence in the range of species in the two grand divisions of the organic world. The six principal regions sketched out in 1857 by Dr. Sclater for birds (referring rather to the genera and families in the class Aves than to the species),* are applicable, with some slight exceptions, to quadrupeds, reptiles, insects, and landshells, and to a great extent even to plants. The regions alluded to are as follows:—1. The Neotropical, comprising South America, Mexico, and the West Indies. 2. The Neoarctic, including the rest of America. 3. The Palæarctic, composed of Europe, Northern Asia as far as Japan, and Africa north of the Sahara. 4. The Ethiopian, which contains the rest of Africa and Madagascar. 5. The Indian, containing Southern Asia and the western half of the Malay Archipelago. 6. The Australian, which comprises the eastern half of the Malay islands, Australia, and most of the Pacific islands.

Some modifications of this arrangement have been since proposed. Mr. Andrew Murray, in his 'Geographical Distribution of Mammalia,' unites the Ethiopian and Indian regions, and divides North America between the Palæarctic and Neotropical regions, thus reducing the principal divisions to three. Professor Huxley † makes two primary divisions, Arctogæa and Notogæa, the latter comprising the Neotropical and Australian regions, the former the rest of the globe Yet although there is still some difference of opinion as to

* Paper read to Linnæan Society, June, 1857.
† Proc. Zool. Soc. 1868, p. 294.

which are primary and which secondary divisions, and as to where the boundary between some of them is to be drawn, Dr. Sclater's regions are generally admitted to be natural ones, and are, in the present state of our knowledge, the best that can be used to illustrate the problems of the geographical distribution of animals.

Neotropical region.—To begin with the Neotropical, comprehending the West Indies and South America. The bird fauna of this division is, according to Dr. Sclater, the richest and most peculiar on the globe, and the mammalia are, as Buffon remarked, singularly unlike those of the Old World. I have already spoken of the Platyrrhine monkeys of South America, as well as of the sloths and armadilloes of that country, and I might add the vampires or true blood-sucking bats (*Phyllostomidæ*), also the capybara, the largest of the rodents, the carnivorous coati-mondi (*Nasua*), with a great many other forms.

If there be any truth in the theory which refers the origin of species to variation or gradual transmutation, we should expect that South America would contain a terrestrial fauna very distinct from that of other lands; for we are taught by geology that the present continents and oceanic basins are of very high antiquity,* and the southern part of the American continent is separated by a wide expanse of sea from Africa, Asia, and the land of the Antarctic regions. We cannot suppose South America to have had a free land communication with any other of the great continents in the Pliocene or scarcely perhaps in the Miocene epoch; so that even the genera of quadrupeds in Europe must have changed several times, while this Neotropical region has continued almost as isolated as it is now.

In Peru and Chili, says Humboldt, the region of the grasses is inhabited at an elevation of from 12,300 to 15,400 feet by crowds of lama, guanaco, and alpaca. These quadrupeds, which here represent the genus camel of the ancient continent, have not extended themselves either to Brazil or Mexico, because, during their journey, they must necessarily have descended into regions that were too hot for them.†

* See above, Vol. I. p. 253. † Description of the Equatorial Regions: 1814.

In this passage, published in 1814, it will be seen that already the doctrine of specific centres was tacitly assumed.

I have already stated that extinct genera of the lama, sloth, armadillo, and many other families of South American quadrupeds, have been found in the same region in a fossil state. But it is remarkable that, in some points, the fossil fauna is not so unlike that of the rest of the world as is the recent. A species of horse, for example, has been found fossil in the Pampas, and of elephant (*Mastodon Andium*) in the mountains of Peru. So also the horse, mastodon, and Siberian mammoth occur fossil throughout a considerable area in North America, although there were no representatives of any of these genera extant in the New World when it was first colonised by Europeans.

The former wide range of these quadrupeds implies a migration of Old-World forms into the New World, perhaps by way of the Andes, in Pliocene times; but how this invasion was brought about, and by what causes the Old-World species were again exterminated, we cannot conjecture. It may, however, be affirmed that we are by no means entitled, in the present state of our knowledge, to wonder at the extinction of any species. A small insect, which lays its eggs in the navels of horses, cattle, and dogs, when first born, makes it impossible, says Darwin, for any of these animals to run wild in Paraguay;* and we are extremely ignorant as to the various animals and plants, on the coexistence of which the well-being of any one species may depend.

Besides, as geologists, we must remember that the horse tribe and the elephants have been waning groups since the Miocene and Pliocene periods in the northern hemisphere. In northern India alone, the fossil remains of the Sewâlik hills have shown us that there were in the Upper Miocene period no less than seven distinct species of proboscidians of the genera *Elephas*, *Mastodon*, and *Stegodon* (as defined by Falconer), and besides these several species of mastodon flourished contemporaneously in Europe. There are now only two living representatives of the whole group, viz. *Elephas*

* Darwin, 'Origin of Species,' 4th edition, p. 83.

Indicus and *E. Africanus*. In like manner no less than twelve equine species referred by Leidy to seven genera, have been already detected in the Pliocene and Post-Pliocene formations of the United States, no one of which survived in America at the time when it was first visited by Europeans.*

It has been objected that the insect fauna of Chili, although to a great extent peculiar to South Temperate America, contains also many generic forms of butterflies and beetles, such as Colias, Carabus and others, which are common to the northern hemisphere, and are not found in the intermediate tropical region. These insects, however, may well be supposed to have passed from north to south along the higher region of the Andes, during the cold of the Glacial Period; and almost all of them seem to have been so modified in their character, that the allied forms of the north and south are not specifically identical. As to the marsupial opossums of America having Australian affinities, it has been justly remarked by Mr. Wallace that as the genus Didelphis existed in Europe in the Eocene and Lower Miocene periods, the American species are much more likely to have been derived from that source, assuming the origin of species by variation, than from Australia, where the genus in question has not hitherto been met with, either in a fossil or living state.

In this great province, the Neotropical, as indeed in every other to which we shall afterwards allude, the larger part of the species are separable from each other by lines of demarcation, whether in the animal or vegetable kingdoms, sufficiently clear to enable naturalists to agree for the most part in their systems of classification; but exceptions could be given in every great division, whether of the vertebrate or invertebrate class, where species occur which pass one into the other by so many intermediate gradations that scarcely any two naturalists take exactly the same views as to their relationship. Thus for example, Mr. Bates observed in the valley of the Amazons swarms of a gregarious species of

* See Leidy and Hayden on Nebraska Fossil Remains, Proc. of Acad. Nat. Sci. Philadelp. 1858, p. 89.

butterfly of the elegant genus *Heliconius*, which is peculiar to tropical America. It abounds in the shades of the forest, presenting clusters of allied species and varieties, as well as some better marked forms. A conspicuous member of the group is *H. Melpomene* of Linnæus, which is found throughout Guiana, Venezuela, and parts of New Granada. It is very common at Obydos on the north side of the Amazons, and reappears on the south side of the river, in the dry forests behind Santarem. But it is absent from other parts of the valley, where a nearly allied species, *H. Thelxiope*, of the same size and shape, but differing in colour, takes its place. Both species have the same habits, and they have always been considered by entomologists as specifically distinct; but Mr. Bates came to the conclusion that one was simply a modification of the other; for he found that in those forest tracts which were intermediate in character between the dryer air of Obydos and the moister air of the rest of the great valley the individuals of these Heliconii were transitional forms between the two reputed species alluded to. He observed them to pass by very slight variations from one extreme to the other, and yet the inference that they were hybrids produced by the intercrossing of *H. Melpomene* and *H. Thelxiope* was not admissible; for the two butterflies were never seen to pair with each other, and the intermediate varieties are unknown in several places where the two forms come in contact. If the whole district which they inhabit is contemplated, the intermediate forms are incomparably more rare than the two extreme terms of the series, and these last must, says Mr. Bates, be treated as good and true species, because they exhibit characters usually regarded as sufficient for such a distinction, and, amongst others, an aversion to pair together. A similar course of reasoning induced the same naturalist to believe in the derivation of *H. Vesta* from *H. Melpomene*, *H. Vesta* having a very wide range, and extending into the central valleys of the Andes.

The highest class of the mammalia, or the monkeys of the same region, might afford us another equally apposite illustration. There are two distinct species of Cebus, or Capuchin monkey, the Caiarara (*C. albifrons*, Spix), and that called

Prego (*C. cirrhifer*, St. Hilaire), both found on the Amazons, which differ in form and disposition. They are not local varieties, for they sometimes co-exist in the same district. But there are so many sub-species and varieties of this same monkey in equatorial America, which spread over thousands of miles of wild country, and connect together the two forms above mentioned, that, after comparing the whole, Mr. Bates affirms that a zoologist cannot separate, by any well-defined line, the two extremes of the series.*

The naming of these varieties has often been a subject of great perplexity in the Zoological Gardens in London, and equally so in the museums at Paris, as anyone may satisfy himself by consulting the printed catalogue, drawn up by Isidore Geoffroy St. Hilaire. Nor are the Capuchins the only platyrrhine monkeys whose classification is embarrassing, as appears by the same official document. To those who adopt Mr. Darwin's views, these transitional forms are precisely what we ought to encounter, for they simply imply, as before hinted, p. 324, that some genera and species are comparatively modern, so that there has not been time for the causes of extinction to make gaps in the series of new varieties.

Neoarctic region.—We have next to pass to the Neoarctic region, extending from the centre of the table-land of Mexico to the North Pole. If we compare the southern limits of this great province with the nearest lands on the east and west, the north of Africa on the one side and China on the other, we find a complete dissimilarity between the fauna of the American and that of the African and Asiatic continents; but, the farther we go north and enter those latitudes where the three continents approach each other, the more the discordance in genera and species diminishes. It has often, indeed, been said that the whole circumpolar region forms one province; but some of the American species formerly identified with the European—the badger, for example—have been found to differ on closer examination, and the musk-ox (*Ovibos moschatus*) is peculiar to America, although the same

* Bates, Naturalist on the Amazons, vol. ii. p. 101.

animal formerly ranged, as we know from its fossil remains, over Germany, France, and England.

The predominant influence of climate over all the other causes which limit the range of species in the mammalia is perhaps nowhere so conspicuously displayed as in the region now under consideration. It will be observed that on this continent between the Rocky Mountains and the Atlantic there are no great geographical barriers running east and west, such as high snow-clad mountains, barren deserts, or wide arms of the sea, capable of checking the free migration of species from north to south. Yet the arctic fauna, so admirably described by Sir John Richardson, has scarcely any species in common with the fauna of the State of New York, which is 600 miles farther south, and comprises about forty distinct mammifers. If again we travel farther south about 600 miles, and enter another zone, running east and west, in South Carolina, Georgia, Alabama, and the contiguous States, we again meet with a new assemblage of land quadrupeds, and this again differs from the fauna of Texas farther to the south, where frosts are unknown. But notwithstanding the distinctness of those zones of indigenous mammalia, there are some species, such as the buffalo (*Bison Americanus*), the racoon (*Procyon lotor*), and the Virginian opossum (*Didelphis Virginiana*), which have a wider habitation, ranging almost from Canada to the Gulf of Mexico; but they form exceptions to the general rule. The opossum of Texas (*Didelphis cancrivora*) is different from that of Virginia, and other species of the same genus are found westward of the Rocky Mountains, in California, for example, where almost all the mammalia differ specifically from those in the United States:

Palæarctic region.—We next come to the third or Palæarctic region, comprising Europe and Northern Asia as far as Japan, and also including Africa north of the desert of the Sahara. Selecting our examples here, as before, chiefly from the mammalia, we may first mention the extraordinary range from east to west of the European species of quadrupeds; for no less than 44 of these, out of 58, are common to Europe and Amoorland, or that part of North-eastern Asia which lies between latitude 45° and 55° north. In the same group

there are some species which have not so wide a range east and west, but which extend for great distances in a north and south direction. Thus the tailless hare, or *Pica*, passes far into the Arctic latitudes, and the tiger, *Felis Tigris*, into the tropical, even as far south as Java.

The propriety of considering Morocco, Algeria, and Tunis as part of the same province as Europe and Northern Asia, has been questioned, but only with reference to the mammals; for the birds, reptiles, insects, and plants are all decidedly of Palæarctic forms. As to the mammalia, Mr. Wallace has given a table showing that no less than thirty-three of the Algerian species are absolutely identical with European or West-Asiatic quadrupeds; fourteen more are representatives of European *genera*, and ten belong to *genera* of Western Asia and Siberia. But, on the other hand, seven or eight species have been supposed to give an Ethiopian or extra-European character to the North-African highlands. They are all desert-haunting species—an antelope, a monkey (*Macacus Inuus*), the same as that which inhabits the rock of Gibraltar, a lion, leopard, cerval, and hunting leopard. These same large feline species range through the whole of Africa from the Mediterranean to the Cape, and may, says Mr. Wallace, very probably have crossed the desert in the tracks of caravans. If we confine our attention to the genera instead of species, we find that out of thirty-one only three are common to the Palæarctic and Ethiopian regions.

From what we have said in the first volume (p. 497) of the submarine ridge between Gibraltar and the nearest part of Africa or Tangiers (a ridge twenty-two miles long and from five to seven miles broad, and nowhere covered by a depth of water exceeding 220 fathoms), we learn that the union of Southern Europe with Africa does not imply a great change in the relative level of land and sea. The geologist at least is familiar with the fact that the rising and sinking of land and of the bed of the Mediterranean within the newer Pliocene Period has, in Sicily and elsewhere, far exceeded the amount which would be required to unite the coasts on the opposite sides of the Straits of Gibraltar. A change of level of about 70 fathoms would

unite Malta and Gozo with Sicily, and one of 200 fathoms would join Malta to Tripoli by an isthmus 170 miles long. A similar change would connect Italy with Sicily, and the latter with Africa by the Adventure Bank. We can only explain, by this and other analogous land communications of modern geological date, the remarkable resemblance of the fauna and flora of the islands of the Mediterranean and of the nearest mainland, notwithstanding the general depth of that sea. Some of the mountainous islands, it is true, of the Egean are inhabited by peculiar species of landshells, as was ascertained by the late Edward Forbes and Captain Spratt; but these mountains may perhaps have been insulated from a remote period, as freshwater strata of Miocene age occur in parts of them, and the surrounding sea is of vast depth. The remains of the African elephant and of the *Elephas antiquus*, and of an extinct hippopotamus in Sicily, and, what is more wonderful, of several species of elephant, and an hippopotamus in caverns in the small island of Malta, bear testimony to great geographical changes in comparatively modern or Pliocene times.

As to the distinctness above alluded to of the North-African fauna from that south of the Sahara, we know that the Great Desert was submerged beneath the sea in the Pliocene Period; so that assuming that species have only one birthplace, we can account for their distinctness in these two regions, which were separated first by a barrier of water and afterwards by one of sand.

The geographical distribution of reptiles agrees as a general rule with that of the mammalia and birds; but a discrepancy has been pointed out in the Palæarctic region. Although the batrachians of Japan are all Palæarctic, the snakes agree in genera and species with those of the more southern parts of Asia or the Indian region, which we shall have presently to consider. Mr. Wallace suggests the following explanation of this apparent anomaly: he reminds us that Dr. Günther has shown that snakes are a preeminently tropical group, decreasing rapidly in the temperate regions, and absolutely ceasing at 62° N., whereas the batrachians are almost as largely developed in northern

as in tropical latitudes, being able to support the most intense cold.* We may therefore suppose Japan to have once formed a part of Northern Asia, with which it is even now almost connected by two chains of islands; in which case it might have received its birds, mammals, and batrachians from the Palæarctic region, whereas it could have derived but few or no snakes from the same quarter, since the great cold extends to a much lower latitude in Eastern Asia than in Western Europe. If at a subsequent period Japan became connected with Southern Asia through the Loo-choo and Majicosima islands, it might then have been colonised by snakes of Indian origin, which would easily establish themselves in a region unoccupied by any representatives of the same class. Batrachians, on the contrary, as well as the birds and mammals of Southern Asia, would find a firmly established Palæarctic population ready to resist the invasion of all intruders.†

Ethiopian region.—The next or fourth zoological province is the Ethiopian, including Africa south of the Great Desert, and the island of Madagascar. That this part of Africa should be characterised by a peculiar indigenous fauna is a fact in perfect accordance with Buffon's theory of natural barriers.

We have already stated that the sea even in post-tertiary times covered the space now occupied by the Sahara, so that Africa was for vast periods surrounded by water on every side but the north-east, where it was connected by an isthmus with Asia. Such a connection might explain why there are some few species, such as the lion, dromedary, and jackal, common to Africa and Asia, and also why many Asiatic genera are represented by allied African species. The elephant, for example, of Africa, though so nearly resembling that of India, is distinct, being smaller, having a rounder head and larger ears than the Indian one, and having only three instead of four toes on each hind foot. There are three African species of rhinoceros, all differing from the three Indian ones. The genus hippopotamus is now represented by two species

* Günther on Geographical Distribution of Snakes, Proc. Zool. Soc. 1858, p. 374.

† Wallace on Zoological and Botanical Geography, Nat. Hist. Rev. 1864. p. 114.

exclusively African, although it occurred in India in the Miocene Period, and in Europe in the Pliocene and Post-Pliocene. Also the giraffe, the gorilla, the chimpanzee, the blue-faced baboon, the four-fingered monkey (*Colobus*), and many carnivora, such as *Proteles*, allied to the hyæna. In proportion as we advance towards the southern part of the Ethiopian region we find in the temperate zone other forms, many of them agreeing generically with those inhabiting the zone of corresponding climate north of the equator in Asia. Among these are the quagga and the zebra; answering to the horse, the ass, and the jiggetai of temperate Asia. Among pachydermatous animals the hyrax is peculiar, among the ruminantia the Cape buffalo and many antelopes, such as the springbok, the oryx, the gnu, the leucophoë, the pygarga, and several others.

Separated from Africa by the Mozambique channel, which is 300 miles wide, Madagascar, with two or three small islands in its immediate vicinity, forms a zoological sub-province, of which all the species except one, and nearly all the genera, are peculiar. The one exception alluded to consists of a small insectivorous quadruped (*Centetes*), found also in the Mauritius, to which place, however, it is supposed to have been taken in ships. The most characteristic feature of this remarkable fauna consists in the number of quadrumana of the Lemur family, no less than six genera of those monkeys being exclusively met with in this island, and a seventh genus of the same, called *Galago*, which alone has any foreign representative, being found, as we might from analogy have anticipated, on the nearest mainland. Madagascar is nearly as large as Great Britain, and being in the same latitude as the adjoining part of the continent of Africa, enjoys a similar climate. Had the species of quadrupeds in Madagascar agreed with those of Africa, as do those of England with the rest of Europe, the naturalist would have inferred that there had been a land communication since the period of the coming in of the existing quadrupeds, whereas we may now conclude that the broad Mozambique channel has constituted an insuperable barrier to the fusion of the continental fauna with that of the great island during the whole

period that has elapsed since the living species of mammalia came into being.

The period when Madagascar was united to some part of Africa was probably as remote as the Upper Miocene era, at which time we know that the outline of the land in Europe varied materially from that which it now exhibits; so that we may readily suppose the arm of the sea constituting the Mozambique channel to have been dry land at that period. Some of the peculiar Miocene genera may have survived on the island after they became extinct on the continent, and a still greater number of species. Other families, such as the Lemurs, may have multiplied more in the island than on the continent; but in spite of such changes the two faunas continental and insular (assuming the origin of species by variation and natural selection) would continue to bear the mark of having sprung from a common source at a comparatively modern era. They would continue to have more affinity with each other than with any more distant region, such as the Indian or Australian. On the other hand, the hypothesis of special creation helps us in no way to account for such generic and family ties as bind together these two sets of animals in each of which all the species are distinct.

Indian region.—We have next to consider the Indian region, comprising Southern Asia and the western half of the Malay Archipelago. Its boundary on the side of Arabia has not yet been well defined, as that country seems at present to be regarded by zoologists as debateable ground between the Ethiopian, Indian, and Palæarctic regions. Although the Indian species are very distinct from those of Africa, a great many of the genera of quadrupeds are common to both continents. There are, however, some forms which are peculiar to the Indian region; such as the sloth-bear (*Prochilus*), the musk-deer (*Moscus*), the nylghau, the gibbon or long-armed ape, and some others.

The elephant and tapir of Sumatra and Borneo are the same as the Indian species, and the rhinoceros of Sumatra and that of Java are each of them respectively common to Bengal and Malacca. One of the gibbons or long-armed apes (*Hylobates leuciscus*) is common to the Malay peninsula and the

islands of Java and Borneo, though wanting in Sumatra. The wild ox of Java also occurs on the Asiatic continent. None of these large animals, says Mr. Wallace, could possibly have passed over the arms of the sea which now separate these countries; so that they point clearly to the existence of a land communication between the islands and the mainland since the origin of such mammalia.

Between 80 and 90 mammals inhabit Java, and nearly as many occur in Sumatra; more than half of these species are common to the two islands. Borneo, which is much less explored, has yielded already upwards of 60 species, and more than half of these are not met with either in Java or Sumatra. As each island contains not only many species but some genera peculiar to itself, the date of their former union can only be spoken of as modern when we understand the term in a geological sense. We may feel sure, for example, that it occurred during some part of the Pliocene epoch; and this speculation is rendered the more probable by the fact that a difference of level of 50 fathoms, or only 300 feet, would unite Borneo, Java, and Sumatra with the mainland, or with Malacca and Siam,* and a rise of 100 fathoms would include the Philippine Islands and Bali or the whole of the Indian region (see map, fig. 138). To this question of a modern geographical change we shall again refer.

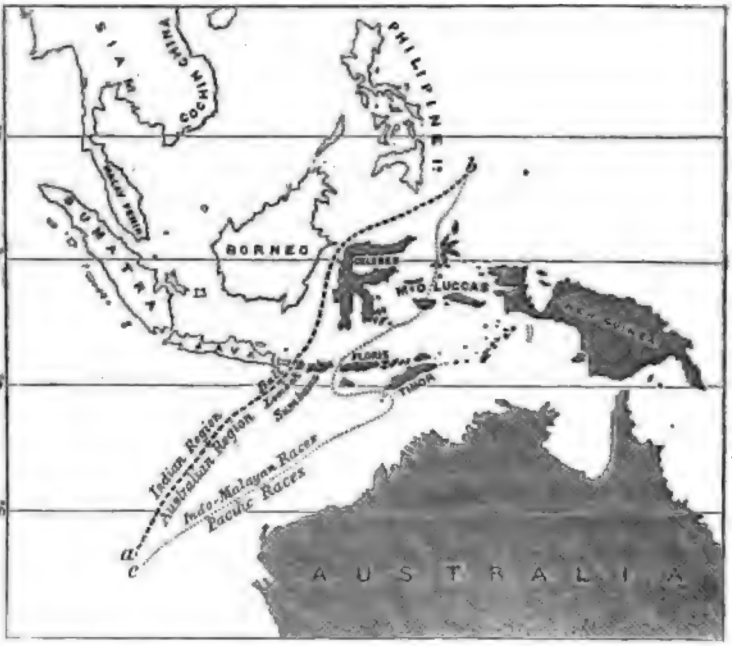
In regard to the birds of the mainland, the genus *Euplocamus* of the pheasant family affords a good illustration of a variable form. Thus *E. melanotus*, or black-backed kalige of Sikkim, is found to pass by numerous varieties in the intermediate Aracan country into the *E. lineatus* of Tenasserim and Pegu. The varieties are considered by Dr. Sclater not to be hybrid forms.

Australian region—and Mr. Wallace on the boundary between it and the Indian region in the Malay Archipelago.—Lastly, we come to the sixth or Australian region, which, as we have before mentioned, is inhabited by mammalia belonging almost exclusively to the marsupial sub-class. The only associated and indigenous placental species are a few rodents and bats. Although the mainland of Australia is very isolated, yet when the

* Wallace, Geog. Soc. Journ 1864, and Malay Archipelago, Vol. I., p. 17.

whole geological province is considered, there seems at first sight to be no natural barrier sufficiently strong in a north-west direction to account for the marked line of separation in the islands of the Malay Archipelago between the species belonging to the Australian and those proper to the Indian region.

Fig. 138.



Map showing the boundaries of two great zoological provinces, the Indian and the Australian, as defined by Alfred R. Wallace, Esq. The lands which are shaded belong to the Australian, the unshaded to the Indian region.

a b. Line exceeding 100 fathoms in depth separating the Indian and Australian zoological regions.

c b. Boundary line between the Malayan and Papuan races, showing their near coincidence with the range of species of the inferior animals (see Chap. XLIII.).

The geographical distribution of the two faunas, which are remarkably distinct, is shown in the annexed map, all the lands which are shaded belonging to the Australian and those which are unshaded to the Indian region. Mr. Wallace has also pointed out that the line *a b*, which divides two different assemblages of mammalia and birds, coincides very nearly with

the line *c b*, which divides two of the best characterised races of mankind, the Malayan and the Pacific, in which last are included the Papuans, Australians, and Polynesians.*

The Straits of Lombok, through which the line *a b* passes between the island of that name and Bali, are only fifteen miles across, less wide than the Straits of Dover, and yet the contrast between the animals of various classes on both sides of this narrow channel is as great as that between those of the Old and New Worlds. In other words, the discordance, not only in species but in genera, equals that which is usually caused by a wide ocean rather than by straits which allow of one shore being easily seen from the other. It has already been stated (p. 349) that all those islands of the Malay Archipelago which are only separated from the mainland of Asia by a depth of water of less than 100 fathoms contain a fauna which is strictly Indian. Mr. Wallace, in commenting on this fact, has pointed out the obvious relation of the present distribution of animals and plants to changes in the position of land and sea, which must be assumed to have taken place in comparatively modern times.

The reader has already been told (Chapters XII., XIV., and XXXI.) of the elevation and depression of the crust of the earth and the conversion of land into sea and sea into land, with which geology has made us acquainted, and of the accompanying fluctuations in the state of the organic world. Taking these for granted, we may expect to find proofs that some islands were once united with each other or with the neighbouring continents at comparatively recent periods. Where this has happened, the same species of animals and plants will be found to be common to the lands now disjoined, and the seas which divide them will usually be shallow. But if the natural productions are dissimilar, we may safely speculate on the separation having taken place at a more remote epoch, as in the case before mentioned of Madagascar and Africa, where we have seen that the intervening sea is very deep.

The line *a b* in the map, fig. 138, indicates a line of sounding exceeding 100 fathoms, the sea to the westward of this

* See below, Chap. XLIII.

line having everywhere a depth of less than 100 fathoms; and here we find the limits of the two faunas, the Indian and the Australian, very sharply defined. When speaking of the contrast of the animals inhabiting the two regions, Mr. Wallace says: 'In Australia there are no apes or monkeys, no cats or tigers; no wolves, bears, or hyænas; no deer, or sheep, or oxen; no elephant, horse, squirrel, or rabbit; none, in short, of those familiar types of quadrupeds which are met with on the Indian area. Instead of these Australia has its marsupials, kangaroos, opossums, and wombats, and the representatives of a still lower division of the mammalia, the duck-billed Platypus (or Ornithorynchus), and the Echidna. Its birds,' he continues, 'are almost as peculiar: it has no woodpeckers and no pheasants, families which exist in every other part of the world. But instead of them it has the mound-making brush-turkeys, the honeysuckers, the cockatoos, and the brush-tongued Lories, which are found nowhere else upon the globe.'*

If we cross the straits from Lombok to Bali, which we may do in two hours, we find on the western side a complete contrast in animal life. We meet, for example, with barbets, fruit-thrushes, and woodpeckers; instead of honeysuckers and brush-turkeys. In like manner, if we travel from Java or from Borneo, and pass over to Celebes, the Moluccas, and New Guinea, the difference is almost equally striking. In Java or Borneo the forests abound in monkeys of many kinds, and wild cats, deer, civets, otters, and squirrels are constantly met with. In Celebes or the Moluccas, none of these occur, but the prehensile-tailed opossum is the terrestrial animal most seen. Some pigs, however, and deer of Indian types, probably introduced by man, are met with.

Mr. Wallace moreover reminds us that the diversity in the natural productions of the two great regions does not correspond to any of the physical or climatal divisions of the surface. On both sides of the line of demarcation we find in the same latitude islands of volcanic origin similar in soil, elevation, moisture, dryness, and fertility, and equally covered

* Wallace, Journal of Geographical Society, 1864, and Malay Archipelago, Vol. I., p. 21.

with forests. How then are we to explain the distinctness of the two faunas? The greater depth of the sea which separates the lands east of the line *a b* (fig. 138) from those to the west of it would lead us to speculate on a longer period of separation. Still it may be asked, how is it possible to conceive that a channel in one place only fifteen miles wide should have been so effective in arresting the migration of species from one region into the other? Before we give an account of Mr. Wallace's speculations on this head, we must state, that marked as is the contrast on the opposite sides of the line *a b*, some colonisation from one province to the other has already begun, although less perhaps than along any one of the points of contact of the five great zoological provinces before described. In Lombok there are several mammalia of the placental class. The largest of them is the ape called *Macacus cynomolgus*. As to the wild pig, it may have been introduced by man, and the same may be said of the Moluccan deer, which occurs in the island of Timor. The *Paradoxurus musanga* of the weasel tribe, also found in many of these islands east of the line *a b*, is an animal often domesticated. But a shrew-mouse and a feline animal, *Felis megalotus*, peculiar to Timor, are less easily explained; unless, indeed, our acquaintance with the mammalia of Java is still defective, a supposition by no means improbable. The squirrels extend from Lombok eastward as far as Sumbawa, but no farther.

In the case of Borneo and Celebes there seems to have been a partial fusion of the mammalia at some remote period, as there is a species of baboon, a wild cat, and a squirrel in Celebes, all belonging to Indian *genera;* but that so few of the mammals of Borneo should have reached Celebes, and that there should be hardly a land-bird in common and very few insects, is, perhaps, says Mr. Wallace, even more extraordinary than the distinctness of the fauna of Bali and Lombok; for the two latter islands being wholly of volcanic origin, may be comparatively modern, whereas Borneo and Celebes must from their great size and altitude be very ancient. Between the latter also, although the sea is much wider than in the Straits of Lombok, there is a

great extent of opposing coasts which would be very favourable to mutual immigration.

It is a singular fact that there are distinct species of wild pig in almost every large island, as in Sumatra, Borneo, Java, New Guinea, and Timor, and one or more other species are said to inhabit Gilolo. Some of these may have been introduced by man at so remote a period as to have varied greatly from the parent stock; for if the prevailing opinion be correct, that the Japanese pigs, of which specimens were lately exhibited at the Zoological Gardens, be mere varieties of the domesticated *Sus Indica*, we may imagine a little more divergence to be sufficient to constitute a true species. We shall see in the next chapter, p. 358, that pigs have been known, when swept by a flood into the sea, to swim for great distances, so that some of them may have passed in this manner from island to island.

That so few quadrupeds, birds, and insects have obtained a footing on the opposite sides of such channels as those of Lombok or the Macassar Straits, seems the more strange, when we reflect on well-known instances of birds even of weak flight having sometimes been carried by the wind during heavy gales over wide spaces of sea. But the power of preoccupancy is great in enabling the old indigenous inhabitants to prevent stray individuals of foreign species from effecting a permanent settlement. As to the Straits of Lombok, they are very narrow, but there is so rapid a marine current always running through them, that it might easily prevent quadrupeds and reptiles from swimming across from shore to shore.

To assist us in accounting for the marked separation between the Indian and Australian faunas, as well as for many partial exceptions to the distinctness of the two groups of animals in some of the islands of the Malay Archipelago, Mr. Wallace has suggested an imaginary parallel, of which I can only give a brief outline. Suppose the bed of the Atlantic to be gradually converted into land, partly by the deposition of large bodies of sediment poured down by rivers, and partly by slow upheaval and volcanic action. Let the two continents of Africa and America be

thus more and more extended, so that the ocean, which now separates them, should at last be reduced to an arm of the sea a few hundred miles wide. Let us, at the same time, imagine several islands to be upheaved in mid-channel, and that, while the subterranean forces varied in intensity and shifted their points of greatest action, these islands became sometimes connected with the main-land on one side of the strait, and sometimes with the land on the other side. Two or more of the islands also might occasionally be joined together and then broken up again, till at last, after many ages of such intermittent action, with many a long intervening period of comparative tranquillity, we might have an irregular archipelago of islands filling up the ocean channel of the Atlantic, in whose appearance and arrangement we could discover nothing to tell us which had been connected with Africa and which with America. But the animals and plants inhabiting these islands would certainly reveal this portion of their former history. On those islands which had ever formed a part of the South American continent we should be certain to find such common birds as chatterers, toucans, macaws, and humming-birds, and some peculiar quadrupeds, such as spider-monkeys, pumas, tapirs, ant-eaters, and sloths; while, on the islands which had been separated from Africa, we should be equally sure to meet with horn-bills, orioles, and honeysuckers, and some quadrupeds contrasting strongly with those of South America, such as baboons, lions, elephants, buffaloes, and giraffes. Those intermediate islands which at different times had had a temporary connection with either continent, would contain a certain amount of mixture in their living inhabitants. Such seems to Mr. Wallace to have been the case with the islands of Celebes and the Philippines. Other islands, again, though in such close proximity as Bali and Lombok, might each exhibit an almost unmixed sample of the productions of the continents of which they had directly or indirectly once formed a part.

In the Malay Archipelago we have indications of a vast Australian continent which once reached westward to the island of Celebes, and was characterised by a very peculiar

fauna and flora; the western part of this continent was afterwards broken up gradually and irregularly into islands. At the same time Asia, which at first was separated from the Australian continent by a wide ocean, appears to have been extending its limits in a south-east direction in an unbroken mass, so as to include Sumatra, Java, and Borneo, and probably reaching as far as the present 100 fathom line of soundings, or as far as the boundary line *a b*, map, fig. 138. Afterwards the south-eastern portion of this land was separated into islands as we now see it, some of them coming into almost actual contact with the scattered fragments of the great Southern or Australian land.

There are some peculiarities in the distribution of animals and plants in oceanic islands which have a more direct and obvious bearing on the question of the origin of species by variation than the grouping of species on continental tracts. I shall therefore consider that subject in a separate chapter;* but as I shall be unable to reason on the somewhat exceptional facts which these islands present in relation to theories of the origin of species, without constantly adverting to the relative powers of migration which different species enjoy, I shall treat of this latter subject first in order, and then allude to the insular faunas and floras.

* Chapter XLI.

CHAPTER XXXIX.

ON THE MIGRATION AND DIFFUSION OF TERRESTRIAL ANIMALS.

MIGRATION OF QUADRUPEDS—MIGRATORY INSTINCTS—DRIFTING OF ANIMALS ON ICE-FLOES—MIGRATION OF BIRDS—MIGRATION OF REPTILES—INVOLUNTARY AGENCY OF MAN IN THE DISPERSION OF ANIMALS.

Migration of quadrupeds.—Before we consider the geographical distribution of aquatic animals, it may be useful to enquire what facilities the terrestrial species enjoy of spreading themselves over the surface of the earth. The tendency of each species to multiply is so great, that unless checked it would soon extend its range over as wide an area as is accessible to it. Whether it feed on plants or prey on other animals, it will not cease to enlarge the boundaries of its habitation until its progress is arrested by some rival species better fitted to the soil, climate, and organic conditions of the country; or by some lofty and unbroken chain of mountains which it cannot scale, or by a desert, or the sea, or by cold or heat, or some other barrier.

Mr. Wallace and Mr. Bates have shown that large rivers such as the Amazons and Rio Negro are capable of forming effective barriers to the farther spread of many species of monkeys. This happens even where the same kind of forest occurs on the opposite banks. Mr. Darwin also mentions that the biscacha, a rodent somewhat resembling a large rabbit, which abounds in the Pampas, although it has crossed the broader river Paranà, has never been able to extend its range across the Uruguay. Geology teaches us that the present continents have been formed by the union of large pre-existing islands; and what were formerly straits of the sea have often become, under a new arrangement of the land, broad valleys and the channels of great rivers such as the Amazons, the Orinoco, and the La Plata. It is therefore

probable that the real obstacle to the farther spread of many species is not their inability to swim over large rivers, but the pre-occupancy of the land on the farther side by an assemblage of animals fitted for all the stations which the region affords. If an intruder attempts to colonise, he is overpowered by a rival species already established in great numbers.* But for such resistance scarcely any quadrupeds would be stopped by rivers and narrow friths; for the greater part of them swim well, and few are without this power when urged by danger and pressing want. Thus, amongst beasts of prey, the tiger is seen swimming about among the islands and creeks in the delta of the Ganges, and the jaguar traverses with ease the largest streams in South America.† The bear, also, and the bison, cross the current of the Mississippi. The popular error, that the common swine cannot escape by swimming when thrown into the water, has been contradicted by several curious and well-authenticated instances during the floods in Scotland of 1829. One pig, only six months old, after having been carried down from Garmouth to the bar at the mouth of the Spey, a distance of a quarter of a mile, swam four miles eastward to Port Gordon, and landed safe. Three others, of the same age and litter, swam, at the same time, five miles to the west, and landed at Blackhill.

In an adult and wild state, these animals would doubtless have been more strong and active, and might, when hard pressed, have performed a much longer voyage, especially if aided by powerful tides and currents. Hence islands many miles distant from a continent may obtain inhabitants by casualties which, like the storms of 1829 in Morayshire, may only occur once in many centuries, or thousands of years, under all the same circumstances.

The late Edward Forbes told me that when he was on board a surveying vessel commanded by Lieutenant Graves, R.N., in the Grecian Archipelago, the sailors amused themselves with setting a terrier at a domestic pig which they had recently purchased. The animal being worried, threw

* Andrew Murray. Geographical Distribution of Mammalia, 1866, p. 18.
† Buffon, vol. v. p. 204.

himself overboard and made for the nearest land in sight, which was many miles distant. As the pig was more fit for the table than for feats of agility, and as the reputation of his tribe for swimming stood very low, the sailors were slow in getting out the boat to give chase, so that the animal having a fair start, landed soon after sunset, just as they came up to him, and further pursuit in the dark was impossible. These facts help to explain the exceptionally wide distribution of pigs already mentioned (p. 354) in the Malay Archipelago, where several distinct species are found in the Moluccas and New Guinea. The *Sus papuensis* of the latter island is the only non-marsupial terrestrial animal known to inhabit it.

The power of crossing rivers is essential to the elephant in a wild state, for the quantity of food which a herd of these animals consumes renders it necessary that they should be constantly moving from place to place. The elephant crosses the stream in two ways. If the bed of the river be hard, and the water not of too great a depth, he fords it. But when he crosses great rivers, such as the Ganges and the Niger, the elephant swims deep, so deep that the end of his trunk only is out of the water; for the complete immersion of his body is a matter of indifference to him, provided he can bring the tip of his trunk to the surface, so as to breathe the external air.

Animals of the deer kind frequently take to the water, especially in the rutting season, when the stags are seen swimming for several leagues at a time, from island to island, in search of the does, especially in the Canadian lakes; and in some countries where there are islands near the sea-shore, they fearlessly enter the sea and swim to them. In hunting excursions, in North America, the elk of that country is frequently pursued for great distances through the water.

The large herbivorous animals, which are gregarious, can never remain long in a confined region, as they consume so much vegetable food. The immense herds of bisons (*Bos Americanus*) which often, in the great valleys of the Mississippi and its tributaries, blacken the surface of the prairie lands, are continually shifting their quarters, followed by wolves,

which prowl about in their rear. 'It is no exaggeration,' says Mr. James, 'to assert, that in one place, on the banks of the Platte, at least ten thousand bisons burst on our sight in an instant. In the morning we again sought the living picture; but upon all the plain, which last evening was so teeming with noble animals, not one remained.'*

Migratory instincts.—Besides the disposition common to the individuals of every species slowly to extend their range in search of food, in proportion as their numbers augment, a migratory instinct often developes itself in an extraordinary manner, when, in consequence of an unusual number of births or of a sudden scarcity of provisions, great multitudes are threatened with famine. It may be useful to enumerate some examples of these migrations, because they may put us upon our guard against attributing a high antiquity to a particular species merely because it is diffused over a great space: they show clearly how soon, in a state of nature, any species might spread itself in every direction, from a single point, and how the territory of one animal may be invaded by another, leading occasionally to the extermination of the weaker species.

In very severe winters, great numbers of the black bears of America migrate from Canada into the United States; but in milder seasons, when they have been well fed, they remain and hybernate in the north.† The rein-deer, which in Scandinavia scarcely ever ranges to the south of the sixty-fifth parallel, descends, in consequence of the greater coldness of the climate, to the fiftieth degree in Chinese Tartary, and often roves into a country of more southern latitude than any part of England.

In Lapland, and other high latitudes, the common squirrels, whenever they are compelled, by want of provisions, to quit their usual abodes, migrate in amazing numbers, and travel directly forwards, allowing neither rocks nor forests, nor the broadest waters, to turn them from their course. In like manner the small Norway rat sometimes pursues its migrations in a straight line across rivers and lakes; and Pennant

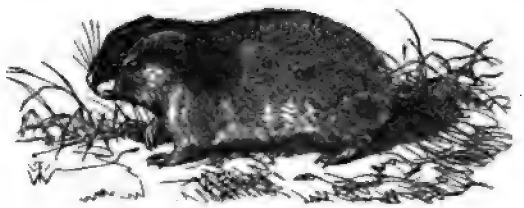
* Expedition from Pittsburg to the Rocky Mountains, vol. ii. p. 153.

† Richardson's Fauna Boreali-Americana, p. 16.

informs us, that when the rats, in Kamtschatka, become too numerous, they gather together in the spring, and proceed in great bodies westward, swimming over the rivers, lakes, and arms of the sea. Many are drowned or destroyed by water-fowl or fish. As soon as they have crossed the river Penginsk, at the head of the gulf of the same name, they turn southward, and reach the rivers Judoma and Okotsk by the middle of July; a district more than 800 miles distant from their point of departure.

The lemings, also, a small kind of rat, are described as natives of the mountains of Kolen, in Lapland; and once

Fig. 139.



The Leming or Lapland Marmot (*Mus Lemmus*, Linn.)

or twice in a quarter of a century they appear in vast numbers, advancing along the ground and 'devouring every green thing.' Innumerable bands march from the Kolen, through Northland and Finmark, to the Western Ocean, which they immediately enter; and after swimming about for some time, perish. Other bands take their route through Swedish Lapland to the Bothnian Gulf, where they are drowned in the same manner. They are followed in their journeys by bears, wolves, and foxes, which prey upon them incessantly. They generally move in lines, which are about three feet from each other, and exactly parallel, going directly forward through rivers and lakes; and when they meet with stacks of hay or corn, gnawing their way through them instead of passing round.* These excursions usually precede a rigorous winter, of which the lemings seem in some way forewarned.

Vast troops of the wild ass, or *onager* of the ancients, which

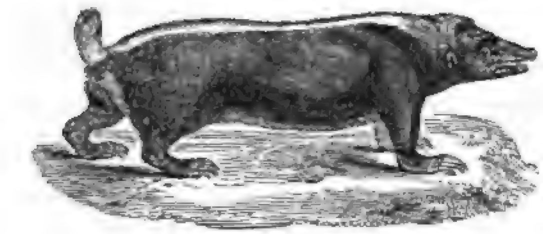
* Phil. Trans., vol. ii. p. 872.

inhabit the mountainous deserts of Great Tartary, feed, during the summer, in the tracts east and north of Lake Aral. In the autumn they collect in herds of hundreds, and even thousands, and direct their course towards the north of India, and often to Persia, to enjoy a warm retreat during winter.* Bands of two or three hundred quaggas (a species of wild ass) are sometimes seen to migrate from the tropical plains of Southern Africa to the vicinity of the Malaleveen River. During their migrations they are followed by lions, who slaughter them night by night.†

The migratory swarms of the springbok, or Cape antelope, afford another illustration of the rapidity with which a species under certain circumstances may be diffused over a continent. When the stagnant pools of the immense deserts south of the Orange River dry up, which often happens after intervals of three or four years, myriads of these animals desert the parched soil, and pour down like a deluge on the cultivated regions near the Cape. The havoc committed by them resembles that of the African locusts; and so crowded are the herds, that 'the lion has been seen to walk in the midst of the compressed phalanx with only as much room between him and his victims as the fears of those immediately around could procure by pressing outwards.'‡

Dr. Horsfield mentions a singular fact in regard to the geographical distribution of the *Mydaus meliceps*, an animal

Fig. 140.



Mydaus meliceps, or badger-headed Mydaus. Length, including the tail, 16 inches.

intermediate between the polecat and badger. It inhabits Java, and is 'confined exclusively to those mountains

* Wood's Zoography, vol. i. p. 11.

† On the authority of Mr. Campbell. Library of Entert. Know., Menageries, vol. i. p. 152.

‡ Cuvier's Animal Kingdom by Griffiths, vol. ii. p. 109. Library of Entert. Know., Menageries, vol. i. p. 336.

which have an elevation of more than 7,000 feet above the level of the ocean; and there it occurs with the same regularity as many plants. The long-extended surface of Java, abounding with isolated volcanos with conical points which exceed this elevation, affords many places favourable for its resort. On ascending these mountains, the traveller scarcely fails to meet with this animal, which, from its peculiarities, is universally known to the inhabitants of these elevated tracts, while to those of the plains it is as strange as an animal from a foreign country. In my visits to the mountainous districts, I uniformly met with it; and, as far as the information of the natives can be relied on, it is found on all the mountains.' *

Now, if asked to conjecture how the Mydaus arrived at the elevated regions of each of these isolated mountains, we might say that, before the island was peopled by man, by whom their numbers are now thinned, they may occasionally have multiplied so as to be forced to collect together and migrate: in which case, notwithstanding the slowness of their motions, some few would succeed in reaching another mountain, some twenty, or even, perhaps, fifty miles distant; for although the climate of the hot intervening plains would be unfavourable to them, they might support it for a time, and would find there abundance of insects on which they feed. Volcanic eruptions, which at different times have covered the summits of some of those lofty cones with sterile sand and ashes, may have occasionally contributed to force on these migrations.

Drifting of animals on ice-floes.—The power of the terrestrial mammalia to cross the sea is very limited, and it was before stated that the same species is scarcely ever common to districts widely separated by the ocean. If there be some exceptions to this rule, they generally admit of explanation; for there are natural means whereby some animals may be floated across the water, and the sea may, in course of ages, wear a wide passage through a neck of land, leaving individuals as a species on each side of the new channel. Polar bears are known to have been frequently drifted on the ice from Greenland to Iceland: they can also swim to considerable

* Horsfield, Zoological Researches in Java, No. ii., from which the figure is taken.

distances, for Captain Parry, on the return of his ships through Barrow's Straits, met with a bear swimming in the water about midway between the shores, which were about forty miles apart, and where no ice was in sight.* 'Near the east coast of Greenland,' observes Scoresby, 'they have been seen on the ice in such quantities, that they were compared to flocks of sheep on a common; and they are often found on field-ice, above two hundred miles from the shore.'† Wolves, in the arctic regions, often venture upon the ice near the shore, for the purpose of preying upon young seals, which they surprise when asleep. When these ice-floes get detached, the wolves are often carried out to sea; and though some may be drifted to islands or continents, the greater part of them perish, and have been often heard in this situation howling dreadfully, as they die by famine.‡

During the short summer which visits Melville Island, various plants push forth their leaves and flowers the moment the snow is off the ground, and form a carpet spangled with the most lively colours. These secluded spots are reached annually by herds of musk-oxen and rein-deer, which, migrating from the North-American continent, traverse the ice for hundreds of miles to graze undisturbed on these luxuriant pastures.§ The rein-deer often pass along in the same manner, by the chain of the Aleutian Islands, from Behring's Straits to Kamtschatka, subsisting on the moss found in these islands during their passage.‖ But the musk-ox, notwithstanding its migratory habits, and its long journeys over the ice, does not exist either in Asia or Greenland.¶

On floating islands of drift-wood.—Within the tropics there are no ice-floes; but, as if to compensate for that mode of transportation, there are floating islets of matted trees, which are often borne along through considerable spaces. These are sometimes seen sailing at the distance of fifty or one hundred miles from the mouth of the Ganges, with living trees standing

* Append. to Parry's Second Voyage, years 1819–20.

† Account of the Arctic Regions, vol. i. p. 518.

‡ Turton in a note to Goldsmith's Nat. Hist., vol. iii. p. 43.

§ Supplement to Parry's First Voyage of Discovery, p. 189.

‖ Godman's American Nat. Hist., vol. i. p. 22.

¶ Dr. Richardson, Brit. Assoc. Report, vol. v. p. 161.

erect upon them. The Amazons, the Orinoco, and the Congo also produce these verdant rafts, which are formed in the manner already described when speaking of the great raft of the Atchafalaya, an arm of the Mississippi, where a natural bridge of timber, ten miles long, and more than two hundred yards wide, existed for more than forty years, supporting a luxuriant vegetation, and rising and sinking with the water which flowed beneath it.

On these green islets of the Mississippi, young trees take root, and the water-lily or nenuphar displays its yellow flowers: serpents, birds, and the cayman alligator come to repose there, and all are sometimes carried to the sea, and engulphed in its waters.

Spix and Martius relate that, during their travels in Brazil, they were exposed to great danger while ascending the Amazons in a canoe, from the vast quantity of drift-wood constantly propelled against them by the current; so much so, that their safety depended on the crew being always on the alert to turn aside the trunks of trees with long poles. The tops alone of some trees appeared above water, others had their roots attached to them with so much soil that they might be compared to floating islets. On these, say the travellers, we saw some very singular assemblages of animals, pursuing peacefully their uncertain way in strange companionship. On one raft were several grave-looking storks, perched by the side of a party of monkeys, who made comical gestures, and burst into loud cries, on seeing the canoe. On another was seen a number of ducks and divers, sitting by a group of squirrels. Next came down, upon the stem of a large rotten cedar-tree, an enormous crocodile, by the side of a tiger-cat, both animals regarding each other with hostility and mistrust, but the saurian being evidently most at his ease, as conscious of his superior strength.*

Similar green rafts, principally composed of canes and brushwood, are called 'camelotes' on the Paranà in South America; and they are occasionally carried down by inundations, bearing on them the tiger, cayman, squirrels, and other quadrupeds, which are said to be always terror-stricken

* Spix and Martius, Reise, &c., vol. iii. pp. 1011, 1013.

on their floating habitation. No less than four tigers (pumas) were landed in this manner in one night at Monte Video, lat. 35° S., to the great alarm of the inhabitants, who found them prowling about the streets in the morning.*

In a memoir published in the United Service Journal (No. XXIV. p. 697) a naval officer relates that, as he returned from China by the eastern passage, he fell in, among the Moluccas, with several small floating islands of this kind, covered with mangrove-trees interwoven with underwood. The trees and shrubs retained their verdure, receiving nourishment from a stratum of soil which formed a white beach round the margin of each raft, where it was exposed to the washing of the waves and the rays of the sun. The occurrence of soil in such situations may easily be explained; for all the natural bridges of timber which occasionally connect the islands of the Ganges, Mississippi, and other rivers, with their banks, are exposed to floods of water, densely charged with sediment.

The late Admiral W. H. Smyth informed me, that, when cruising in the Cornwallis amidst the Philippine Islands, he saw more than once, after those dreadful hurricanes called typhoons, floating masses of wood, with trees growing upon them. Ships have sometimes been in imminent peril, as these islands were often mistaken for terra firma, when, in fact, they were in rapid motion.

It is highly interesting to trace, in imagination, the effects of the passage of these rafts from the mouth of a large river to some barren island, raised from the deep by the operations of the volcano and the earthquake. If a storm arise, and the frail vessel be wrecked, still many a bird and insect may succeed in gaining, by flight, some point on the newly-formed island, while the seeds and berries of herbs and shrubs, which fall into the waves, may be washed up on the strand. But if the surface of the deep be calm, and the raft is carried along by a current, or wafted by some slight breath of air fanning the foliage of the green trees, it may arrive, after a passage of several weeks, in some bay of the island, into which its plants and animals may be poured out as from an ark, and

* Sir W. Parish's Buenos Ayres, p. 187, and Robertson's Letters on Paraguay, p. 220.

thus a colony of several hundred new species may at once be naturalised.

Although the transportation of such rafts may be of extremely rare and accidental occurrence, and may happen only once in thousands or tens of thousands of years, they may yet account in tropical countries for the extension of some species of mammalia, birds, insects, landshells, and plants to lands which without such aid they could never have reached.

Migration of birds.—It was before stated that birds, notwithstanding their great locomotive powers, form no exception to the general rule, that groups of distinct species are circumscribed within definite limits.

In parallel zones of the northern and southern hemispheres, a great general correspondence of form is observable, both in the aquatic and terrestrial birds; but there is rarely any specific identity: and this phenomenon is remarkable, when we consider the readiness with which some birds, not gifted with great powers of flight, shift their quarters to different regions, and the facility with which others, possessing great strength of wing, perform their aërial voyages. Many species migrate periodically from high latitudes, to avoid the cold of winter, and the accompaniments of cold,—scarcity of insects and vegetable food. For this purpose, they often traverse the ocean for thousands of miles, and recross it at other periods, with equal security.

Periodical migrations, no less regular, are mentioned by Humboldt, of many American water-fowl, from one part of the tropics to another, in a zone where there is the same temperature throughout the year. Immense flights of ducks leave the valley of the Orinoco, when the increasing depth of its waters and the flooding of its shores prevent them from catching fish, insects, and aquatic worms. They then betake themselves to the Rio Negro and the Amazons, having passed from the eighth and third degrees of north latitude to the first and fourth of south latitude, directing their course south-south-east. In September, when the Orinoco decreases and re-enters its channels, these birds return northwards.*

The insectivorous swallows which visit our island would

* Voyage aux Régions Equinoxiales, tom. vii. p. 429.

perish during winter, if they did not annually repair to warmer climes. It is supposed that in these aërial excursions the average rapidity of their flight is not less than fifty miles an hour; so that, when aided by the wind, they soon reach warmer latitudes. Spallanzani calculated that the swallow can fly at the rate of ninety-two miles an hour, the rapidity of the swift being much greater.* Bachman says that the hawk, wild pigeon (*Columba migratoria*), and several species of wild ducks, in North America, fly at the rate of forty miles an hour, or nearly a thousand miles in twenty-four hours.†

It is well known that many European birds are carried every winter during violent gales of wind from Europe to the Azores. Some of them are supposed to be blown from Great Britain to those islands.‡ In performing such flights no great exertion of muscular power may be required, if they have simply to extend their wings and allow themselves to be carried through the air in the direction of the wind. If they advance at the rate even of twenty miles an hour, they would reach the islands in forty-eight hours, a period not exceeding that during which many birds can sustain life without food (see below, p. 418).

When we reflect how easily different species, in a great lapse of ages, may be each overtaken by gales and hurricanes, and, abandoning themselves to the tempest, be scattered at random through various regions of the earth's surface, where the temperature of the atmosphere, the vegetation, and the animal productions might be suited to their wants, we shall be prepared to find some species capriciously distributed, and to be sometimes unable to determine the native countries of each. Admiral Smyth, when engaged in his survey of the Mediterranean, encountered a gale in the Gulf of Lyons, at the distance of between twenty and thirty leagues from the coast of France, which bore along many land-birds of various species, some of which alighted on the ship, while others were thrown with violence against the sails. In this manner islands may become tenanted by species of birds inhabiting the nearest mainland.

* Fleming, Phil. Zool., vol. ii. p. 43.

† Silliman's Amer. Journ. No. 61, p. 83.

‡ Mr. F. Du Cane Godman, Ibis, vol. ii. 1866, New Series.

Migration of reptiles.—Turtles migrate in large droves from one part of the ocean to another during the ovipositing season; and they find their way annually to the island of Ascension, from which the nearest land is about 800 miles distant. Dr. Fleming mentions, that an individual of the hawk's bill turtle (*Chelonia imbricata*), so common in the American seas, has been taken at Papa Stour, one of the West Zetland Islands; * and, according to Sibbald, 'the same animal came into Orkney.' Another was taken, in 1774, in the Severn, according to Turton. Two instances, also, of the occurrence of the leathern tortoise (*C. coriacea*), on the coast of Cornwall, in 1756, are mentioned by Borlase. These animals of more southern seas can be considered only as stragglers attracted to our shores during uncommonly warm seasons by an abundant supply of food, or carried by the Gulf-stream, or driven by storms to high latitudes.

Some of the smaller reptiles lay their eggs on aquatic plants; and these may often be borne rapidly by rivers, and thus conveyed to distant regions.

But that even the larger ophidians may be transported across the seas, is evident from the following most interesting account of the arrival of one at the island of St. Vincent. It is worthy of being recorded, says Mr. Guilding, 'that a noble specimen of the *Boa constrictor* was lately conveyed to us by the currents, twisted round the trunk of a large sound cedar-tree, which had probably been washed out of the bank by the floods of some great South-American river, while its huge folds hung on the branches, as it waited for its prey. The monster was fortunately destroyed after killing a few sheep, and his skeleton now hangs before me in my study, putting me in mind how much reason I might have had for fear in my future rambles through the forests of St. Vincent, had this formidable reptile been a pregnant female, and escaped to a safe retreat.' †

Involuntary agency of man in the dispersion of animals.—In a future chapter I shall speak of the transportation by man to distant regions of quadrupeds and birds which are useful

* Brit. Animals, p. 149, who cites Sibbald.

† Zool. Journ. vol. iii. p. 406. Dec. 1827.

to him, and of the effect of such colonisation in limiting the range and sometimes extirpating indigenous species of plants and animals. I shall merely consider in this place the involuntary or unintentional aid which we frequently lend to the dissemination of species, many of them not only unserviceable but noxious and injurious to us.

Thus we have introduced the rat, which was not indigenous in the New World, into all parts of America. It has been conveyed over in ships, and now infests a great multitude of islands and parts of that continent. In like manner the Norway rat (*Mus decumanus*) has been imported into England, where it plunders our property in ships and houses.

Among birds, the house-sparrow may be cited as a species known to have extended its range with the tillage of the soil. During the last century it has spread gradually over Asiatic Russia towards the north and east, always following the progress of cultivation. It made its first appearance on the Irtisch in Tobolsk, soon after the Russians had ploughed the land. It came in 1735 up the Obi to Beresow, and four years after to Naryn, about fifteen degrees of longitude farther east. In 1710, it had been seen in the higher parts of the coast of the Lena, in the government of Irkutzk. In all these places it is now common, but is not yet found in the uncultivated regions of Kamtschatka.*

The great viper, or 'Fer de lance' (*Cras pedocephalus lanceolatus*), a native of the mainland of South America, and no less venomous than the rattlesnake, now ravages Martinique and St. Lucia into which it was accidentally introduced by man, and exists in no other part of the West Indies.

Many parasitic insects which attack our persons, and some of which are supposed to be peculiar to our species, have been carried into all parts of the earth, and have as high a claim as man to a *universal* geographical distribution.

A great variety of insects have been transported in ships from one country to another, especially in warmer latitudes. The European house-fly has been introduced in this way into all the South Sea Islands. Notwithstanding the coldness of

* Gloger, Abänd. der Vögel, p. 103; Pallas, Zoog. Rosso-Asiat., tom. ii. p. 197.

our climate in England, we have been unable to prevent the cockroach (*Blatta orientalis*) from entering and diffusing itself in our ovens and kneading-troughs, and availing itself of the artificial warmth which we afford. It is well known also that beetles, and many other kinds of ligniperdous insects, have been introduced into Great Britain in timber; especially several North-American species. 'The commercial relations,' says Malte-Brun,* 'between France and India, have transported from the latter country the aphis, which destroys the apple-tree, and two sorts of Neuroptera, the *Lucifuga* and *Flavicola*, mostly confined to Provence and the neighbourhood of Bordeaux, where they devour the timber in the houses and naval arsenals.'

Among mollusks we may mention the *Teredo navalis*, which is a native of equatorial seas, but which, by adhering to the bottom of ships, was transported to Holland, where it has been most destructive to vessels and piles. The same species has also become naturalised in England, and other countries enjoying an extensive commerce. *Bulimus undatus*, a land species of considerable size, which is a native of Jamaica and other West Indian islands, has been imported, adhering to tropical timber, into Liverpool; and, as Mr. Broderip informed me, is now naturalised in the woods near that town.

In all these and innumerable other instances we may regard the involuntary agency of man as strictly analogous to that of the inferior animals. Like them, we unconsciously contribute to extend or limit the geographical range and numbers of certain species, in obedience to general rules in the economy of nature, which are for the most part beyond our control.

* Syst. of Geog., vol. viii. p. 169.

CHAPTER XL.

ON THE GEOGRAPHICAL DISTRIBUTION AND MIGRATION OF SPECIES—*continued.*

GEOGRAPHICAL DISTRIBUTION AND MIGRATION OF FISH—OF TESTACEA—OF INSECTS—MOTHS SEEN FLYING 300 MILES FROM LAND—BOTANICAL GEOGRAPHY—DISPERSION OF PLANTS—AGENCY OF RIVERS AND CURRENTS—MARINE PLANTS—SARGASSUM OR GULF-WEED—AGENCY OF ANIMALS IN THE DISTRIBUTION OF PLANTS—AGENCY OF MAN, BOTH VOLUNTARY AND INVOLUNTARY, IN THE DISPERSION OF PLANTS.

Geographical distribution and migration of fish.—Although we are less acquainted with the habitations of marine animals than with those of terrestrial species, yet it is well ascertained that their distribution is governed by the same general laws.

On comparing the freshwater fish of Europe and North America, Sir John Richardson remarks, that the only species which is unequivocally common to the two continents is the pike (*Esox lucius*); and it is curious that this fish is unknown to the westward of the Rocky Mountains, the very coast which approaches nearest to the old continent.* According to the same author the genera of freshwater fish in China agree closely with those of the peninsula of India, but the species are not the same. 'As in the distribution,' he adds, 'of marine fish, the interposition of a continent stretching from the tropics far into the temperate or colder parts of the ocean, separates different ichthyological groups; so with respect to the freshwater species, the intrusion of arms of the sea running far to the northwards, or the interposition of a lofty mountain chain, effects the same thing. The freshwater fish of the Cape of Good Hope and the South-American ones, are different from those of India and China.' †

Cuvier and Valenciennes, in their 'Histoire des Poissons,'

* Brit. Assoc. Reports, vol. v. p. 203.
† Report to the Brit. Assoc., 1845, p. 192.

observe that very few species of marine fish cross the Atlantic. But a great many species are common to the opposite sides of the Indian Ocean, inhabiting alike the Red Sea, the eastern coast of Africa, Madagascar, the Mauritius, the southern seas of China, the Malay Archipelago, the northern coasts of Australia, and the whole of Polynesia! * This very wide diffusion, says Sir J. Richardson, may have been promoted by chains of islands running east and west, which are wanting in the deep Atlantic. An archipelago extending far in longitude, favours the migration of fish by multiplying the places of deposit for spawn along the shores of islands, and on intervening coral banks; and in such places, also, fish find their appropriate food.

Although the marine shells on the opposite sides of the Isthmus of Panama are scarcely any one of them the same, yet nearly a third of the marine fishes, or 48 out of 158 species, have recently been ascertained by Dr. Günther to be common to the Pacific Ocean and Caribbean Sea. It has been said in explanation of the species of Testacea being distinct, that the coast on the east side of the isthmus is low, and the sea shallow, whereas the west or Pacific coast is abrupt with perpendicular cliffs. The fish would be much more independent of the physical geography of the coast, and their eggs might be transported from one side of the isthmus to the other by birds.†

The flying fish are found (some stragglers excepted) only between the tropics: in receding from the line, they never approach a higher latitude than the fortieth parallel. The course of the Gulf-stream, however, and the warmth of its water, enable some tropical fish to extend their habitations far into the temperate zone; thus the chætodons, which abound in the seas of hot climates, are found among the Bermudas on the thirty-second parallel, where they are preserved in basins inclosed from the sea, as an important article of food for the garrison and inhabitants. Other fish, following the direction of the same great current, range from the coast of Brazil to the banks of Newfoundland.‡

* Richardson, Brit. Assoc. Reports, 1845, p. 190.

† Gardener's Chronicle, Feb. 23, 1867, p. 181.

‡ Sir J. Richardson, Brit. Assoc. Reports, 1845, p. 190.

All are aware that there are certain fish of passage which have their periodical migrations, like some tribes of birds. The salmon, towards the season of spawning, ascends the rivers for hundreds of miles, leaping up the cataracts which it meets in its course, and then retreats again into the depths of the ocean. The herring and the haddock, after frequenting certain shores, in vast shoals, for a series of years, desert them again, and resort to other stations, followed by the species which prey on them. Eels are said to descend into the sea for the purpose of producing their young, which are seen returning into the fresh water by myriads, extremely small in size, but possessing the power of surmounting every obstacle which occurs in the course of a river, by applying their slimy and glutinous bodies to the surface of rocks, or the gates of a lock, even when dry, and so climbing over it.* Before the year 1800 there were no eels in Lake Wener, the largest inland lake in Sweden, which discharges its waters by the celebrated cataracts of Trolhättan. But according to Professor Nilsson, when a canal was opened uniting the river Gotha with the lake by a series of nine locks, eels were observed in abundance in the lake. It appears, therefore, that though they were unable to ascend the falls, they made their way by the locks, by which in a very short space a difference of level of 114 feet is overcome.

Gmelin says, that the Anseres (wild geese, ducks, and others) subsist, in their migrations, on the spawn of fish; and that oftentimes, when they void the spawn, two or three days afterwards, the eggs retain their vitality unimpaired.† When there are many disconnected freshwater lakes in a mountainous region, at various elevations, each remote from the other, it has often been deemed inconceivable how they could all become stocked with fish from one common source; but it has been suggested, that the minute eggs of these animals may sometimes be entangled in the feathers of waterfowl. These, when they alight to wash and plume themselves in the water, may often unconsciously contribute to propagate swarms of fish, which, in due season, will supply them with food. Some of the water beetles, also, as the

* Phil. Trans. 1747, p. 395. † Amœn. Acad. Essay 75.

Dyticidæ, are amphibious, and in the evening quit their lakes and pools; and, flying in the air, transport the minute ova of fishes to distant waters. In this manner some naturalists account for the fry of fish appearing occasionally in small pools caused by heavy rains.

GEOGRAPHICAL DISTRIBUTION AND MIGRATION OF TESTACEA.

The Testacea are a class of animals of peculiar importance to the geologist; because their remains are found in strata of all ages, and generally in a higher state of preservation than those of other organic beings.

Some forms are exclusively confined to warm, others to cold, latitudes. Marine currents flowing permanently in certain directions, and the influx at certain points of great bodies of fresh water, limit the extension of many species. Those which love deep water are arrested by shoals; others, fitted for shallow seas, cannot migrate across unfathomable abysses. The nature also of the ground has an important influence on the testaceous fauna, both on the land and beneath the waters. Certain species prefer a sandy, others a gravelly, and some a muddy sea-bottom. On the land, limestone is of all rocks the most favourable to the number and propagation of species of the genera Helix, Clausilia, Bulimus, and others. Professor E. Forbes showed in 1843,* as the result of his labours in dredging in the Ægean Sea, that there are eight well-marked regions of depth, each characterised by its peculiar testaceous fauna. The first of these, called the littoral zone, extends to a depth of two fathoms only; but this narrow belt is inhabited by more than 100 species. The second region, of which ten fathoms is the inferior limit, is almost equally populous; and a copious list of species is given as characteristic of each region down to the seventh, which lies between the depths of 80 and 105 fathoms, all the inhabited space below this being included in the eighth province, where no less than 65 species of shell-fish or mollusca have been taken. The majority of the shells in this lowest zone are white or transparent. Only two species are common to

* Brit. Assoc. Reports for 1843, p. 173.

all the eight regions, namely, *Arca lactea* and *Cerithium lima*.* These divisions of Edward Forbes were acknowledged by himself to be probably of no more than partial application, since they were deduced from observations made in an inland sea, and, therefore, under peculiar conditions. In that sea he believed that the zero of animal life would probably be reached at 1,800 feet, but we know that he was aware that this limit was not universal, because he has cited a letter received by him in 1845 from his friend Goodsir, in which this naturalist gave an account of mollusca and other invertebrata dredged up in a living state from a depth of 1,800 feet near Davis Straits.†

Great range of some provinces and species.—In Europe conchologists distinguish between the arctic fauna, the southern boundary of which corresponds with the isothermal line of 32° F., and the Celtic, which, commencing with that limit as its northern frontier, extends southward to the mouth of the English Channel and Cape Finisterre, in France. From that point begins the Lusitanian fauna, which, according to the observations of Mr. M'Andrew in 1852, ranges to the Canary Islands. The Mediterranean province is distinct from all those above enumerated, although it has some species in common with each.

The Indo-Pacific region is by far the most extensive of all. It reaches from the Red Sea and the eastern coast of Africa, to the Indian Archipelago and adjoining parts of the Pacific Ocean. To the geologist it furnishes a fact of no small interest, by teaching us that one group of living species of mollusca may prevail throughout an area exceeding in magnitude the utmost limits we can as yet assign to any assemblage of contemporaneous fossil species. Mr. Cuming obtained more than 100 species of shells from the eastern coast of Africa identical with those collected by himself at the Philippines and in the eastern coral islands of the Pacific Ocean, a distance of 12,000 miles, equal, says Darwin, to that from pole to pole.‡

* Report to the Brit. Assoc. 1843, p. 130.

† Forbes and Godwin-Austen, Natural History of European Seas, 1859, p. 51.

‡ Quart. Journ. Geol. Soc., 1846, vol. ii. p. 268.

Certain species of the genus *Ianthina* have a very wide range, being common to seas north and south of the equator. They are all provided with a beautifully contrived float, which renders them buoyant, facilitating their dispersion, and enabling them to become active agents in disseminating other species. Captain King took a specimen of *Ianthina fragilis* alive, a little north of the equator, so loaded with barnacles (*Pentelasmis*) and their ova that the upper part of its shell was invisible.

Helix putris (*Succinea putris*, Lam.) has a wide range in Europe, occurs also in Siberia, and is said to inhabit Newfoundland and parts of North America. It was found by Captain Hutton in Afghanistan.* As this animal inhabits constantly the borders of pools and streams where there is much moisture, it is not impossible that different waterfowl have been the agents of spreading some of its minute eggs, which may have been entangled in their feathers. The freshwater snail, *Lymnea palustris*, so abundant in English ponds, ranges uninterruptedly from Europe to Cashmere, and thence to the eastern part of Asia. *Helix aspersa*, one of the commonest of our larger land-shells, is found in St. Helena and other distant countries. Some conchologists have conjectured that it was accidentally imported into St. Helena in some ship; for it is an eatable species.

As an illustration of the power of such mollusca to retain life during a long voyage without air or nourishment, I may mention that four individuals of a large species of landshell (*Bulimus*), from Valparaiso, were brought to England by Lieutenant Graves, who accompanied Captain King in his expedition to the Straits of Magellan. They had been packed up in a box, and enveloped in cotton: two for a space of thirteen, one for seventeen, and a fourth for upwards of twenty months: but when they were exposed by Mr. Broderip to the warmth of a fire in London, and provided with tepid water, I saw them revive and feed greedily on lettuce leaves.

Perhaps no species has a better claim to be called cosmopolite than one of our British bivalves, *Saxicava rugosa*. It

* J. Gwyn Jeffreys, British Conchology, p. 152.

is spread over all the north-polar seas, and ranges in one direction through Europe to Senegal, occurring on both sides of the Atlantic; while in another it finds its way into the North Pacific, and thence to the Indian Ocean. Nor do its migrations cease till it reaches the Australian seas.

A British brachiopod, named *Terebratula caput serpentis*, is common, according to Professor E. Forbes, to both sides of the North Atlantic, and to the South-African and Chinese seas. The wide range in space of this species is a fact of peculiar interest to the geologist, because its range in time also is exceptionally great, being one of the very few species which have been traced in a fossil state as far back as the Cretaceous Period.

Mode of diffusion of Testacea,—Notwithstanding the proverbially slow motion of snails and mollusks in general, and although many aquatic species adhere constantly to the same rock for their whole lives, they are by no means destitute of provision for disseminating themselves rapidly over a wide area. 'Some Mollusca,' says Professor E. Forbes, 'migrate in their larva state, for all of them undergo a metamorphosis either in the egg or out of the egg. The Gasteropoda commence life under the form of a small spiral shell, and an animal furnished with ciliated wings, or lobes, like a pteropod, by means of which it can swim freely, and in this form can migrate with ease through the sea.' *

We are accustomed to associate in our minds the idea of the great locomotive powers with the most mature and perfect state of each species of invertebrate animal, especially when they undergo a series of transformations; but in all the Mollusca the reverse is true. The fry of the cockle, for example (*Cardium*), possess, when young or in the larva state, an apparatus which enables them both to swim and to be carried along easily by a marine current. (See fig. 141.)

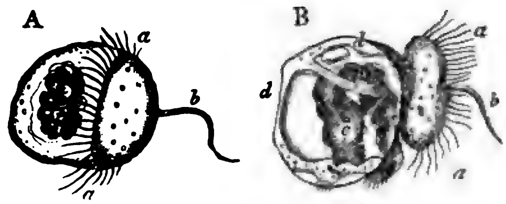
These small bodies here represented, which bear a considerable resemblance to the fry of univalve, or gasteropodous shells, above mentioned, are so minute at first as to be only just visible to the naked eye. They begin to move about from the moment they are hatched, by means of the long

* Edin. New Phil. Journ. April, 1844.

cilia, *a, a,* placed on the edges of the locomotive disk or velum. This disk shrinks up as they increase in size, and gradually disappears, no trace of it being visible in the perfect animal.

Some species of shell-bearing Mollusca lay their eggs in a sponge-like nidus, wherein the young remain enveloped for a

Fig. 141.



The young fry of a cockle (Cardium pygmæum), from Loven's Kongl. Vetenskaps Akadem. Handling, 1848.

A. The young just hatched, magnified 100 diameters.
B. The same farther advanced.
a. The ciliated organ of locomotion with its filamentous appendage *b*.
c. The rudimentary intestine.
d. The rudimentary shell.

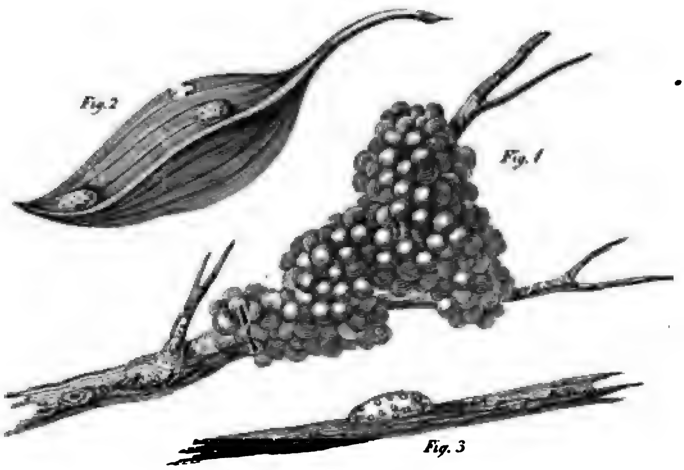
time after their birth; and this buoyant substance floats far and wide as readily as sea-weed. The young of other viviparous tribes are often borne along entangled in sea-weed. Sometimes they are so light, that, like grains of sand, they can be easily moved by currents. Balani and Serpulæ are sometimes found adhering to floating cocoa-nuts, and even to fragments of pumice far out at sea. It is probable, indeed, that the porous and sponge-like texture of pumice causes it to be a vehicle for the transport of eggs of mollusks and insects and of the seeds of plants far more effective in many regions than has been hitherto suspected. Mr. Bates saw pieces of it floating on the river Amazons 1,200 miles from the nearest volcanos of the Andes, from which it must have been derived. He also observed other fragments 900 miles lower down the river, which in the rainy season are floated at the rate of from three to five miles an hour.* They must often reach the sea, and may then be carried by currents hundreds of miles farther.

* Naturalist of the Amazons, vol. ii. p. 170.

In rivers and lakes, on the other hand, aquatic univalves usually attach their eggs to leaves and sticks which have fallen into the water, and which are liable to be swept away, during floods, from tributaries to the main streams, and from thence to all parts of the same basin. Particular species may thus migrate during one season from the head waters of the Mississippi, or any other great river, to countries bordering the sea, at the distance of many thousand miles. An illustration of the mode of attachment of these eggs will be seen in the annexed cut (fig. 142).

A lobster (*Astacus marinus*) was taken alive covered with living mussels (*Mytilus edulis*); * and a large female crab

Fig. 142.



Eggs of freshwater Mollusks.

Fig. 1. Eggs of *Ampullaria ovata* (a fluviatile species) fixed to a small sprig which had fallen into the water.

Fig. 2. Eggs of *Planorbis albus*, attached to a dead leaf lying under water.

Fig. 3. Eggs of the common Limneus (*L. vulgaris*), adhering to a dead stick under water.

(*Cancer pagurus*), covered with oysters, and bearing also *Anomia ephippium*, and Actiniæ, was also taken in 1832, off the English coast. The oysters, seven in number, included individuals of six years' growth, and the two largest were four inches long and three inches and a half broad. †

* The specimen was preserved in the Museum of the Zool. Soc. of London.

† Mr. Broderip observed that this crab, which was apparently in perfect health, could not have cast her shell for six years, whereas some naturalists have stated that the species moults annually, without limiting the moulting period to the early stages of the growth of the animal.

From this example we learn the manner in which oysters may be diffused over every part of the sea where the crab wanders; and if they are at length carried to a spot where there is nothing but fine mud, the foundation of a new oyster-bank may be laid on the death of the crab. In this instance the oysters survived the crab many days, and were killed at last only by long exposure to the air.

GEOGRAPHICAL DISTRIBUTION AND MIGRATION OF INSECTS.

The entomological provinces coincide very closely with those of the higher animals as already described. Few species have a very wide range, but there are exceptions to this rule, and among them may be mentioned our painted lady butterfly (*Vanessa cardui*), which re-appears at the Cape of Good Hope and in New Holland and Japan with scarcely a varying streak.* The same species is said to be one of the few insects which are universally dispersed over the earth, being found in Europe, Asia, Africa, America, and Australia, although it rarely occurs within the tropics except in a few mountain regions. Its wide range seems to imply a capacity enjoyed by few species, of enduring a great diversity of temperature, and is the more interesting because of the migratory instinct which it sometimes displays.

A vast swarm of this species, forming a column from ten to fifteen feet broad, was, in 1826, observed in Switzerland, in the Canton de Vaud: they traversed the country with great rapidity from north to south, all flying onwards in regular order, close together, and not turning from their course on the approach of other objects. Professor Bonelli, of Turin, observed, in March of the same year, a similar swarm of the same species, also directing their flight from north to south, in Piedmont, in such immense numbers that at night the flowers were literally covered with them. They had been traced from Coni, Raconi, Susa, &c. A similar flight at the end of the last century is recorded by M. Louch, in the Memoirs of the Academy of Turin.

The European hive-bee (*Apis mellifica*), although not a

* Kirby and Spence, vol. iv. p. 487; and other authors.

native of the New World, is now established both in North and South America. It was introduced into the United States by some of the early settlers, and has since overspread the vast forests of the interior, building hives in the decayed trunks of trees. 'The Indians,' says Irving, 'consider them as the harbinger of the white man, as the buffalo is of the red man, and say that in proportion as the bee advances the Indian and the buffalo retire. It is said,' continues the same writer, 'that the wild bee is seldom to be met with at any great distance from the frontier, and that they have always been the heralds of civilisation, preceding it as it advanced from the Atlantic borders. Some of the ancient settlers of the west even pretend to give the very year when the honey-bee first crossed the Mississippi.'* The same species is now also naturalised in Van Diemen's Land and New Zealand.

As almost all insects are winged, they can readily spread themselves wherever their progress is not opposed by uncongenial climates, or by seas, mountains, and other physical impediments; and these barriers they can sometimes surmount by abandoning themselves to violent winds, which, as I shall afterwards state when speaking of the dispersion of seeds (p. 390), may in a few hours carry them to very considerable distances. On the Andes some sphinxes and flies have been observed by Humboldt, at the height of 19,180 feet above the sea, and which appeared to him to have been involuntarily carried into these regions by ascending currents of air.†

Inundations of rivers, observes Kirby, if they happen at any season except in the depth of winter, always carry down a number of insects, floating on the surface of bits of stick, weeds, &c.; so that when the waters subside, the entomologist may generally reap a plentiful harvest. In the dissemination, moreover, of these minute beings, as in that of plants, the larger animals play their part. Insects are, in numberless instances, borne along in the coats of animals, or the feathers of birds; and the eggs of some species are capable,

* Washington Irving's Tour in the Prairies, ch. ix.

† Description of the Equatorial Regions,—Malte-Brun, vol. v. p. 379.

like seeds, of resisting the digestive powers of the stomach, and after they are swallowed with herbage, may be ejected again unharmed in the dung.

White mentions a remarkable shower of aphides which seem to have emigrated, with an east wind, from the great hop plantations of Kent and Sussex, and blackened the shrubs and vegetables where they alighted at Selborne, spreading at the same time in great clouds all along the vale from Farnham to Alton. These aphides are sometimes accompanied by vast numbers of the common lady-bird (*Coccinella septempunctata*), which feeds upon them.*

It is remarkable, says Kirby, that many of the insects which are occasionally observed to emigrate, as, for instance, the Libellulæ, Coccinellæ, Carabi, Cicadæ, &c., are not usually social insects; but seem to congregate, like swallows, merely for the purpose of emigration.† Here, therefore, we have an example of an instinct developing itself on certain rare emergencies, causing unsocial species to become gregarious and to venture sometimes even to cross the ocean.

The armies of locusts (*Gryllus migratorius*), which darken the air in Africa and traverse the globe from Turkey to our southern counties in England, are well known to all, and their vast geographical range will again be alluded to (Chap. XLII.). When the western gales sweep over the Pampas they bear along with them myriads of insects of various kinds. As a proof of the manner in which species may be thus diffused, I may mention that when the Creole frigate was lying in the outer roads off Buenos Ayres, in 1819, at the distance of six miles from the land, her decks and rigging were suddenly covered with thousands of flies and grains of sand. The sides of the vessel had just received a fresh coat of paint, to which the insects adhered in such numbers as to spot and disfigure the vessel, and to render it necessary partially to renew the paint.‡ The late Admiral W. H. Smyth was obliged to repaint his vessel, the Adventure, in the Mediter-

* Kirby and Spence, vol. ii. p. 9. 1817.

† Ibid.

‡ I am indebted to Lieutenant Graves, R.N., for this information.

ranean, from the same cause. He was on his way from Malta to Tripoli, when a southern wind blowing from the coast of Africa, then one hundred miles distant, drove such myriads of flies upon the fresh paint, that not the smallest point was left unoccupied by insects.

Moths seen flying 300 *miles from land.*—Captain Henry Toynbee has put on record some striking examples of the great distance from land at which the larger Lepidoptera are occasionally seen on the wing. A female of the large *Sphynx convolvuli* flew on board his ship, the Hotspur, East Indiaman, in lat. 12° 09′ N. and long. 21° 17′ W., a point 300 miles from the nearest coast of Africa, and about 210 miles from the Cape de Verde Islands, from which last it is supposed to have come, as the prevailing winds at the time were north-westerly. Two individuals of the common Death's Head Moth (*Acherontia atropos*) also flew on board the Hotspur during the same homeward voyage, in lat. 40° 29′ N.—long. 15° W., or 260 miles from the nearest land (the coast of Portugal) after an easterly gale. They had already traversed more than two-thirds of the distance from Europe to Madeira, and the case affords a good illustration of the manner in which islands far out at sea may be peopled with insects from the nearest continents.*

To the southward of the river Plate, off Cape St. Antonio, and at the distance of fifty miles from land, several large dragon-flies alighted on the Adventure frigate, during Captain King's expedition to the Straits of Magellan. If the wind abates when insects are thus crossing the sea, the most delicate species are not necessarily drowned; for many can repose on the water without sinking. The slender long-legged Tipulæ, when driven out far from our coast, have been seen standing on the surface of the sea, and they took wing immediately on being approached.† Exotic beetles are sometimes thrown on our shore, which revive after having been long drenched in salt water; and the periodical appearance of some conspicuous butterflies

* Both the above-mentioned insects were shown at a meeting of the Zoological Society by Mr. Flower, May 22, 1866.

† I state this fact on the authority of my friend, the late Mr. John Curtis, the able entomologist.

amongst us, after being unseen some for five, others for fifty years, has been ascribed, not without probability, to the agency of the winds.

BOTANICAL GEOGRAPHY.

Scarcely 1,400 species of plants appear to have been known and described by the Greeks, Romans, and Arabians. At present, more than 3,000 species are enumerated as natives of our own island.* In other parts of the world there have been now collected more than 100,000 reputed species, specimens of which are preserved in European herbariums. It was not to be supposed, therefore, that the ancients should have acquired any correct notions respecting what has been called the geography of plants, although the influence of climate on the character of the vegetation could hardly have escaped their observation.

Antecedently to investigation, there was no reason for presuming that the vegetable productions, growing wild in the eastern hemisphere, should be unlike those of the western, in the same latitude; nor that the plants of the Cape of Good Hope should be unlike those of the south of Europe; situations where the climate is little dissimilar. The contrary supposition would have seemed more probable, and we might have anticipated an almost perfect identity in the plants which inhabit corresponding parallels of latitude at equal heights above the sea. The discovery, therefore, that each separate region of the globe, both of the land and water, is occupied, in the vegetable as well as in the animal world, by distinct groups of species, and that most of the exceptions to this general rule are referable to disseminating causes now in operation, is eminently calculated to prepare us to receive with favour any hypothesis respecting the first introduction of species which is most consistent with such phenomena.

Botanical regions.—Humboldt was among the first to promulgate philosophical views on the distinctness of the vegetable productions of different regions of the globe.

* Barton's Lectures on the Geography of Plants, p. 2. 1827.

Every hemisphere, he said, is inhabited by different species of plants, and it is not by the diversity of climates that we can attempt to explain why equinoctial Africa has no Laurineæ, and the New World no Heaths;* or why the Calceolariæ are found only in the southern hemisphere.

'We can conceive,' he adds, 'that a small number of the families of plants, for instance, the Musaceæ and the Palms, cannot belong to very cold regions, on account of their internal structure and the importance of certain organs; but we cannot explain why no one of the Melastomas (a family allied to the Myrtles) vegetates north of the parallel of thirty degrees; or why no rose-tree belongs to the southern hemisphere. Analogy of climates is often found in the two continents without identity of productions.'†

The luminous essay of Auguste De Candolle on 'Botanical Geography' (1820) presents us with the fruits of his own researches and those of Humboldt, Brown, and other eminent botanists, so arranged, that the principal phenomena of the distribution of plants are exhibited in connection with the causes to which they are supposed to be referable.‡ 'It might not, perhaps, be difficult,' observes this writer, 'to find two points, in the United States and in Europe, or in equinoctial America and Africa, which present all the same circumstances: as, for example, the same temperature, the same height above the sea, a similar soil, an equal dose of humidity; yet nearly all, *perhaps all*, the plants in these two similar localities shall be distinct. A certain degree of analogy, indeed, of aspect, and even of structure, might very possibly be discoverable between the plants of the two localities in question; but the *species* would in general be different. Circumstances, therefore, different from those which now determine the *stations*, have had an influence on the *habitations* of plants.'

It may be as well to define in this place the technical sense in which the words printed in italics are here used: *station*

* The common heath (*Erica vulgaris*, L.) has, since Humboldt wrote, been found growing wild in one spot in Massachusetts north of Boston; but this case is quite exceptional.

† Pers. Nar., vol. v. p. 180.

‡ Essai Elémentaire de Géographie Botanique. Extrait du 18me vol. du Dict. des Sci. Nat. 1820.

indicates the peculiar nature of the locality where each species is accustomed to grow, and has reference to climate, soil, humidity, light, elevation above the sea, and other analogous circumstances; whereas, by *habitation* is meant a general indication of the country where a plant grows wild. Thus the *station* of a plant may be a salt-marsh, a hill-side, the bed of the sea, or a stagnant pool. Its *habitation* may be Europe, North America, or New Holland, between the tropics. The study of *stations* has been styled the topography, that of *habitations* the geography, of botany. The terms thus defined, express each a distinct class of ideas, which have been often confounded together, and which are equally applicable in zoology.

In farther illustration of the principle above alluded to, that difference of longitude, independently of any influence of temperature, is accompanied by a great, and sometimes a complete, diversity in the species of plants, De Candolle observed, that, out of 2,891 species of phænogamous plants described by Pursh as known in 1820 in the United States, there were only 385 common to northern or temperate Europe.

On comparing New Holland with Europe, Mr. Brown ascertained that, out of 4,100 species, then discovered in Australia, there were only 166 common to Europe, and of this small number there were some few which may have been transported thither by man. Almost all of the 166 species were cryptogamic, and the rest consist, in nearly every case, of phænogamous plants which also inhabit intervening regions.

But it is still more remarkable that there should be an almost equal diversity of species, in distant parts of the ancient continent between which there is an uninterrupted land communication. Thus there is one assemblage of species in China, another in the countries bordering the Black Sea and the Caspian, a third in those surrounding the Mediterranean, a fourth on the great platforms of Siberia and Tartary, and so forth.

The distinctness of the groups of indigenous plants, in the same parallel of latitude, is greatest, as in the case of animals before mentioned, where continents are disjoined

by a wide expanse of ocean. In the northern hemisphere, near the pole, where the extremities of Europe, Asia, and America unite or approach near to one another, a considerable number of the same species of plants are found, common to the three continents. But it has been remarked, that these plants, which are thus so widely diffused in the arctic regions, are also found in the chain of the Aleutian islands, which stretch almost across from America to Asia, and which may probably have served as the channel of communication for the partial blending of the floras of the adjoining regions. De Candolle enumerated twenty great botanical provinces, inhabited by indigenous and aboriginal plants; and his son Alphonse, a distinguished living botanist, has made a further subdivision into twenty-seven provinces, between which the lines of demarcation are by no means ill-defined.*

There are, however, not a few species which are common to two or more than two of these provinces, and often representative forms which some naturalists would class as mere geographical varieties. The six ornithological divisions of the globe before alluded to (p. 337), four of them in the Old World and two in the New, are not on the whole inapplicable to plants, if we wish to take a more large and comprehensive view of the leading features in their geographical distribution, especially as regards genera and families.

This holds true, particularly of the Neoarctic and Neotropical regions, each of which contains a distinct assemblage of peculiar vegetable forms. Those of the table-land of Brazil, which has an elevation of from 2,000 to 4,000 feet, are described by Sir Charles Bunbury, after he had explored the district, as belonging for the most part to generic types, little known except to botanists, for they have not been cultivated in Europe. But when he descended from the Brazilian uplands towards the south, or to the grassy plains of Uruguay and La Plata, he found plants still belonging to the predominant South-American types, though represented by different and local species. Such affinity between the specific forms proper to the more elevated and to the lower stations agrees well with the idea of certain original types

* Alph. de Candolle, Monogr. des Campanulées. Paris, 1830.

having been gradually adapted by variation and natural selection to all the diversified conditions of the surface of the land.

The Pampas and banks of the Plata are also remarkable for the extraordinary manner in which some foreign European plants, especially the thistles and trefoils, have overpowered the indigenous vegetation.* The intruders have been introduced by man sometimes unintentionally, and, having naturalised themselves, have become more conspicuous than any of the native products of the soil. They illustrate a principle before laid down, that the organic beings of each great region which man finds in possession of wide areas are not those which are most fitted of all contemporary species to flourish there to the exclusion of all others. They appear to be simply the modified descendants of such an older fauna and flora as happened to pre-exist under a somewhat different phase of the earth's physical geography, or they are the offspring of colonists which by natural means were able to reach those lands. But the same organisms are powerless to maintain their ground in the struggle for life if brought into competition with species from distant regions which would never without the aid of man have come into contact with them.

Marine plants.—The vegetation of the sea, like that of the land, is divisible into different provinces each inhabited by distinct species, but these provinces are fewer in number because the temperature of the ocean is more uniform than that of the atmosphere, and because the area of land bears a small proportion to that of water, so that the migration of marine plants is not so often stopped by barriers of land as is that of the terrestrial species by an intervening ocean. It is a remarkable fact that Dr. Hooker has been able to identify no less than a fifth part of the antarctic algæ, excluding the New Zealand and Tasmanian groups, with British species. Yet there is a much smaller proportion of cosmopolite species among the algæ than among the terrestrial cellular cryptogams, such as lichens, mosses, and Hepaticæ.

* Sir C. Bunbury, 'Characters of S. American Vegetation,' Fraser's Magazine, July, 1867.

Dispersion of plants.—The fact last alluded to, of the ubiquitous character of cryptogamous plants, deserves special attention. Linnæus observed that, as the germs of plants of this class, such as mosses, fungi, and lichens, consist of an impalpable powder, the particles of which are scarcely visible to the naked eye, there is no difficulty in accounting for their being dispersed throughout the atmosphere, and carried to every point of the globe where there is a station fitted for them. Lichens in particular ascend to great elevations, sometimes growing on bare rocks two thousand feet above the line of perpetual snow, where the mean temperature is nearly at the freezing point. This elevated position must contribute greatly to facilitate the dispersion of those buoyant particles of which their fructification consists.*

Some have inferred, from the springing up of mushrooms whenever particular soils and decomposed organic matter are mixed together, that the production of fungi is accidental, and not analogous to that of perfect plants. But Fries, whose authority on these questions is entitled to the highest respect, has shown the fallacy of this argument in favour of the old doctrine of equivocal generation. 'The sporules of fungi,' says this naturalist, 'are so infinite, that in a single individual of *Reticularia maxima*, I have counted above ten millions, and so subtile as to be scarcely visible, often resembling thin smoke; so light that they may be raised perhaps by evaporation into the atmosphere, and dispersed in so many ways by the attraction of the sun, by insects, wind, elasticity, adhesion, &c., that it is difficult to conceive a place from which they may be excluded.' †

The club-moss called *Lycopodium cernuum* affords a striking example of a cryptogamous plant universally distributed over all equinoctial countries. It scarcely ever passes beyond the northern tropic, except in one instance, where it appears around the hot-springs in the Azores, although it is neither an inhabitant of the Canaries nor of Madeira. Doubtless its microscopic sporules are everywhere present, ready to germinate on any spot where they can enjoy throughout

* Linn., Tour in Lapland, vol. ii. p. 282.

† Fries, cited by Lindley, Introd. to Nat. Syst. of Botany.

the year the proper quantity of warmth, moisture, light, and other conditions essential to the species.

No less than 200 species of lichen were brought home from the southern hemisphere by the Antarctic Expedition under Sir James Ross, and almost every one of these was ascertained to be also an inhabitant of the northern hemisphere, and most of them European.

When we contrast the cosmopolite character of this class of plants with the comparatively limited range of most of the phænogamous species, we cannot fail to perceive how intimately the geographical distribution of each is related to its powers of dispersion. But, in order to see a connection between these phenomena, we must first assume that each species has one birthplace, and that it has radiated in all directions in which it is possible for it to spread from the original point or centre where it was first formed.

The most active of the inanimate agents provided by nature for scattering the seeds of plants over the globe, are the movements of the atmosphere and of the ocean, and the constant flow of water from the mountains to the sea. To begin with the winds: a great number of seeds are furnished with downy and feathery appendages, enabling them, when ripe, to float in the air, and to be wafted easily to great distances by the most gentle breeze. Other plants are fitted for dispersion by means of an attached wing, as in the case of the fir-tree, so that they are caught up by the wind as they fall from the cone, and are carried to a distance. Amongst the comparatively small number of plants known to Linnæus, no less than 138 genera are enumerated as having winged seeds.

As winds often prevail for days, weeks, or even months together, in the same direction, these means of transportation may sometimes be without limits; and even the heavier grains may be borne through considerable spaces, in a very short time, during ordinary tempests; for strong gales, which can sweep along grains of sand, often move at the rate of about forty miles an hour, and if the storm be very violent, at the rate of fifty-six miles.* The hurricanes of tropical regions,

* Annuaire du Bureau des Longitudes.

which root up trees and throw down buildings, sweep along at the rate of ninety miles an hour; so that, for however short a time they prevail, they may carry even the heavier fruits and seeds over friths and seas of considerable width, and doubtless are often the means of introducing into islands the vegetation of adjoining continents. Whirlwinds are also instrumental in bearing along heavy vegetable substances to considerable distances. Slight ones may frequently be observed in our fields, in summer, carrying up haycocks into the air, and then letting fall small tufts of hay far and wide over the country; but they are sometimes so powerful as to dry up lakes and ponds, and to break off the boughs of trees, and carry them up in a whirling column of air.

Dr. Franklin tells us, in one of his letters, that he saw, in Maryland, a whirlwind which began by taking up the dust which lay in the road, in the form of a sugar-loaf with the pointed end downwards, and soon after grew to the height of forty or fifty feet, being twenty or thirty in diameter. It advanced in a direction contrary to the wind; and although the rotatory motion of the column was surprisingly rapid, its onward progress was sufficiently slow to allow a man to keep pace with it on foot. Franklin followed it on horseback, accompanied by his son, for three quarters of a mile, and saw it enter a wood, where it twisted and turned round large trees with surprising force. These were carried up in a spiral line, and were seen flying in the air, together with boughs and innumerable leaves, which, from their height, appeared reduced to the size of flies. As this cause operates at different intervals of time throughout a great portion of the earth's surface, it may be the means of bearing not only plants but insects, land testacea and their eggs, with many other species of animals, to points which they could never otherwise have reached, and from which they may then begin to propagate themselves again as from a new centre.

Agency of rivers and currents.—In considering, in the next place, the instrumentality of the aqueous agents of dispersion, I cannot do better than cite the words of one of our ablest botanical writers. 'The mountain stream or

torrent,' observes Keith, 'washes down to the valley the seeds which may accidentally fall into it, or which it may happen to sweep from its banks when it suddenly overflows them. The broad and majestic river, winding along the extensive plain, and traversing the continents of the world, conveys to the distance of many hundreds of miles the seeds that may have vegetated at its source. Thus the southern shores of the Baltic are visited by seeds which grew in the interior of Germany, and the western shores of the Atlantic by seeds that have been generated in the interior of America.'* Fruits, moreover, indigenous to America and the West Indies, such as that of the *Mimosa scandens*, the cashew-nut, and others, have been known to be drifted across the Atlantic by the Gulf-stream, on the western coasts of Europe, in such a state that they might have vegetated had the climate and soil been favourable. Among these the *Guilandina Bonduc*, a leguminous plant, is particularly mentioned, as having been raised from a seed found on the west coast of Ireland.†

Sir Hans Sloane states, that several kinds of beans cast ashore on the Orkney Isles, and Ireland, but none of which appear to have naturalised themselves, are derived from trees which grow in the West Indies, and many of them in Jamaica. He conjectures that they might have been conveyed by rivers into the sea, and then by the Gulf-stream, to greater distances.

The absence of liquid matter in the composition of seeds renders them comparatively insensible to heat and cold, so that they may be carried without detriment through climates where the plants themselves would instantly perish. Such is their power of resisting the effects of heat, that Spallanzani mentions some seeds that germinated after having been boiled in water.‡ Sir John Herschel informed me that he has sown at the Cape of Good Hope the seeds of the *Acacia lophanta* after they had remained for twelve hours in water of 140° Fahrenheit, and they germinated far more rapidly than unboiled seeds. He also stated that an emi-

* System of Physiological Botany, vol. ii. p. 405.

† Brown, Append. to Tuckey, No. v. p. 481.

‡ System of Physiological Botany, vol. ii. p. 403.

nent botanist, Baron Ludwig, could not get the seeds of a species of cedar to grow at the Cape till they were thoroughly boiled.

When, therefore, a strong gale, after blowing violently off the land for a time, dies away, and the seeds alight upon the surface of the waters, or wherever the ocean, by eating away the sea-cliffs, throws down into its waves plants which would never otherwise reach the shores, the tides and currents become active instruments in assisting the dissemination of various classes of the vegetable kingdom. The pandanus and many other plants have been distributed in this way over the islands of the Pacific.

In a collection of 600 plants from the neighbourhood of the river Zaire, in Africa, the late Dr. Robert Brown found that thirteen species were also met with on the opposite shores of Guiana and Brazil. He remarked that most of these plants were found only on the lower parts of the river Zaire, and were chiefly such as produced seeds capable of retaining their vitality a long time in the currents of the ocean. Dr. J. Hooker informs me that after an examination of a great many insular floras, he has found that no one of the large natural orders is so rich in species common to other countries, as the Leguminosæ. The seeds in this order, which comprises the largest proportion of widely diffused littoral species, are better adapted than those of any other plants for water-carriage.

Mr. Darwin has made a series of experiments to ascertain the number of days for which the seeds and fruits of various plants could be immersed in salt water without injury, and he found that out of 87 kinds, 64 germinated after they had been 28 days in salt water, and some survived an immersion of 37 days. According to the average rate at which oceanic currents run, he came to the conclusion that a large number of seeds might be carried uninjured for nearly 1,000 miles across the sea.*

Currents and winds in the arctic regions drift along icebergs covered with an alluvial soil, on which pine-saplings and a variety of herbaceous plants are seen growing, all of

* Origin of Species, chap. xi.

which may continue to vegetate on some distant shore where the ice-island may be stranded.

Dispersion of marine plants.—With respect to marine vegetation, the seeds, being in their native element, may remain immersed in water without injury for indefinite periods, so that there is no difficulty in conceiving the diffusion of species wherever uncongenial climates, contrary currents, and other causes do not interfere. All are familiar with the sight of the floating sea-weed;

> Flung from the rock on ocean's foam to sail,
> Where'er the surge may sweep, the tempest's breath prevail.

I have before called attention (p. 389) to the interesting fact that one-fifth of all the algæ found in the antarctic regions in 1841–3, by Dr. J. Hooker, were of species common to the British seas. He has suggested that cold currents which prevail from Cape Horn to the equator, and are there met by other cold waters, may by their direct influence, as well as by their temperature, facilitate the passage of antarctic species to the Arctic Ocean.

Remarkable accumulations of that species of sea-weed generally known as gulf-weed, or sargassum, occur north of the equator in the Northern Atlantic. Columbus and other navigators, who first encountered these banks of algæ, compared them to vast inundated meadows, and stated that they retarded the progress of their vessels. This mass of floating vegetation, exceeding the British Isles in area, lies between latitudes 20° and 35° to the south-west of Europe.

Sir Hans Sloane stated in 1696 that this weed grows on the rocks about Jamaica, and is known to be 'carried by the winds and current towards the coast of Florida and thence into the North-American ocean, where it lies very thick on the surface of the sea.' *

Humboldt first suggested that it occupies an eddy in that part of the Atlantic where the Gulf-stream is met by the current from the north; and Maury gives a similar explanation of another large bank of kelp and drift-weed in the North Pacific, to the northward of the Sandwich Islands,

* Phil. Trans. 1696.

and of another in the Southern Ocean around Kerguelen's Land between lat. 40° and 54°.*

The late Robert Brown inclined to the opinion that the original source of the gulf-weed might be some parts of the coasts of the Gulf of Florida. When floating on the ocean it propagates itself rapidly by new fronds which are continually pushed out from the old ones; and the larger portion of it being produced under such peculiar circumstances, the plant may perhaps become so modified as not to be easily identifiable with the original stock from which it is derived.† Edward Forbes conceived that this weed first grew on an old coast-line since submerged; this coast having formed the western extremity of the continent of Europe and Northern Africa, which then extended far into the Atlantic.‡ But the great depth of the ocean, ranging from 1,000 to 10,000 feet, and often to a still greater depth, which prevails over a great part of the area assumed by this hypothesis to have been turned from land into sea since the Miocene epoch, makes me consider it far more probable that, instead of growing on a bank which has sunk down, the gulf weed has been drifted from some part of America.

As proof of the extent to which sea-weed is drifted, I may mention that along the northern edge of the Gulf-stream Dr. Hooker found *Fucus nodosus* and *F. serratus*, which he traced all the way from lat. 36° N. to England. The hollow pod-like receptacles in which the spores of many algæ are lodged, and the filaments attached to the seed-vessels of others, seem intended to give buoyancy. It may also be remarked that these hydrophytes are in general *proliferous*, so that the smallest fragment of a branch can be developed into a perfect plant. The spores, moreover, of the greater number of species are enveloped with a mucous matter like that which surrounds the eggs of some fish, and which not only protects them from injury, but serves to attach them to floating bodies or to rocks.

* See map of Sargassum seas, taken from Maury by Andrew Murray, Geog. Dist. of Mammals, 1866.

† R. Brown, Mode of Propagation of Gulf-weed, Miscell. Works, vol. i. Ray Society, 1866.

‡ E. Forbes, Fauna and Flora, &c., 1846, vol. i. p. 349.

Agency of animals in the distribution of plants.—But we have as yet considered part only of the fertile resources of nature for conveying seeds to a distance from their place of growth. The various tribes of animals are busily engaged in furthering an object whence they derive such important advantages. Sometimes an express provision is found in the structure of seeds to enable them to adhere firmly by prickles, hooks, and hairs to the coats of animals, or feathers of the winged tribe, to which they remain attached for weeks, or even months, and are borne along into every region whither birds or quadrupeds may migrate. Linnæus enumerates fifty genera of plants, and the number now known to botanists is much greater, which are armed with hooks, by which, when ripe, they adhere to the coats of animals. Most of these vegetables, he remarks, require a soil enriched with dung. Few have failed to mark the locks of wool hanging on the thorn-bushes, wherever the sheep pass, and it is probable that the wolf and other beasts of prey never give chase to herbivorous animals without being unconsciously subservient to this part of the vegetable economy.

A deer has strayed from the herd when browsing on some rich pasture, when he is suddenly alarmed by the approach of his foe. He instantly takes to flight, dashing through many a thicket, and swimming across many a river and lake. The seeds of the herbs and shrubs which have adhered to his smoking flanks, and even many a thorny spray, which has been torn off, and has fixed itself in his hairy coat, are brushed off again in other thickets and copses. Even on the spot where the victim is devoured many of the seeds which he had swallowed immediately before the chase may be left on the ground uninjured, and ready to spring up in a new soil.

The passage, indeed, of undigested seeds through the stomachs of animals is one of the most efficient causes of the dissemination of plants, and is, of all others, perhaps the most likely to be overlooked. Few are ignorant that a portion of the oats eaten by a horse preserve their germinating faculty in the dung. The fact of their being still nutritious is not lost on the sagacious rook. To many, says Linnæus, it seems

extraordinary, and something of a prodigy, that when a field is well tilled and sown with the best wheat, it frequently produces darnel or the wild oat, especially if it be manured with new dung; they do not consider that the fertility of the smaller seeds is not destroyed in the stomachs of animals.*

Some birds of the order Passeres devour the seeds of plants in great quantities, which they eject again in very distant places, without destroying their faculty of vegetation: thus a flight of larks will fill the cleanest field with a great quantity of various kinds of plants, as the melilot trefoil (*Medicago lupulina*), and others whose seeds are so heavy that the wind is not able to scatter them to any distance.† In like manner, the blackbird and misselthrush, when they devour berries in too great quantities, are known to consign them to the earth undigested in their excrement.‡

Pulpy fruits serve quadrupeds and birds as food, while their seeds, often hard and indigestible, pass uninjured through the intestines, and are deposited far from their original place of growth in a condition peculiarly fit for vegetation.§ So well are the farmers, in some parts of England, aware of this fact, that when they desire to raise a quickset hedge in the shortest possible time, they feed turkeys with the haws of the common white-thorn (*Cratægus Oxyacantha*), and then sow the stones which are ejected in their excrement, whereby they gain an entire year in the growth of the plant.‖ Birds, when they pluck cherries, sloes, and haws, fly away with them to some convenient place; and when they have devoured the fruit, drop the stone into the ground. Captain Cook, in his account of the volcanic island of Tanna, one of the New Hebrides, which he visited in his second voyage, makes the following interesting observation:—'Mr. Forster, in his botanical excursion this day, shot a pigeon, in the craw of which was a wild nutmeg.'¶ It is easy, therefore, to perceive, that birds in their migra-

* Linnæus, Amœn. Acad., vol. ii. p. 409.

† Amœn. Acad., vol. iv. Essay 75. § 8.

‡ Amœn. Acad., vol. vi. § 22.

§ Smith's Introd. to Phys. and Syst. Botany, p. 304. 1807.

‖ This information was communicated to me by Professor Henslow, of Cambridge.

¶ Book iii. ch. iv.

tions to great distances, whether across land or sea, may transport even heavy seeds to new isles and continents.

The sudden deaths to which great numbers of frugivorous birds are annually exposed must not be omitted as auxiliary to the transportation of seeds to new habitations. When the sea retires from the shore, and leaves fruits and seeds on the beach, or in the mud of estuaries, it might, by the returning tide, wash them away again, or destroy them by long immersion; but when they are swallowed by land birds which frequent the sea-side, or by waders and water-fowl, they are often borne inland; and if the bird to whose crop they have been consigned is killed, they may be left to grow up far from the sea. Let such an accident happen but once in a century, or a thousand years, it will be sufficient to spread many of the plants from one continent to another; for in estimating the activity of these causes, we must not consider whether they act slowly in relation to the period of our observation, but in reference to the duration of species in general.

Let us trace the operation of this cause in connection with others. A tempestuous wind bears the seeds of a plant many miles through the air, and then delivers them to the ocean; the oceanic current drifts them to a distant continent; by the fall of the tide they become the food of numerous birds, and one of these is seized by a hawk or eagle, which, soaring across hill and dale to a place of retreat, leaves, after devouring its prey, the unpalatable seeds to spring up and flourish in a new soil.

Mr. Darwin found that fresh-water fish eat the seeds of many land and water plants, and as the same fish are often devoured by birds, such seeds may be readily transported by them to great distances. The same naturalist observed also that the earth adhering to the feet of birds, often contains a variety of seeds of plants; and he mentions one case where from a ball of earth taken from the leg of a partridge he raised more than 80 individual plants belonging to species both of monocotyledons and dicotyledons.* Insects are probably instrumental like birds in disseminating plants, for

* Origin of Species, 4th edition, p. 432.

proofs have lately been obtained (see Chapter XLI.) of the germinating power of seeds swallowed by locusts and rejected in their dung.

The machinery above adverted to, is so capable of disseminating seeds over almost unbounded spaces, that were we more intimately acquainted with the economy of nature, we might probably explain nearly all the instances of plants inhabiting two points very remote from each other and not found in places intermediate; but some difficulties must remain in accounting for the range of species so long as the botanist confines his speculations to the present state of the earth's physical geography and climate. For the geologist can show that great changes have taken place in the height of the land and in the position of land and sea since the greater number of the living species of plants came into being. And we shall see in Chapter XLII. how much the rarity, or even the entire extinction, of species is promoted by these changes.

Agency of man in the dispersion of plants.—But in addition to all the agents already enumerated as instrumental in diffusing plants over the globe, we have still to consider man —one of the most important of all. He transports with him, into every region, the vegetables which he cultivates for his wants, and is the involuntary means of spreading a still greater number which are useless to him, or even noxious. 'When the introduction of cultivated plants,' says De Candolle, 'is of recent date, there is no difficulty in tracing their origin; but when it is of high antiquity, we are often ignorant of the true country of the plants on which we feed. No one contests the American origin of the maize or the potato; nor the origin, in the Old World, of the coffee-tree, and of wheat. But there are certain objects of culture, of very ancient date, between the tropics, such for example as the banana, of which the origin cannot be verified. Armies, in modern times, have been known to carry, in all directions, grain and cultivated vegetables from one extremity of Europe to the other; and thus have shown us how, in more ancient times, the conquests of Alexander, the distant expeditions of the Romans, and afterwards the Crusades, may

have transported many plants from one part of the world to the other.'*

But, besides the plants used in agriculture, the number which have been naturalised by accident, or which man has spread unintentionally, is considerable. One of our old authors, Josselyn, gives a catalogue of such plants as had, in his time, sprung up in the colony since the English planted and kept cattle in New England. They were two-and-twenty in number. The common nettle was the first which the settlers noticed; and the plantain was called by the Indians 'Englishman's foot,' as if it sprung from their footsteps.†

'We have introduced every where,' observes De Candolle, 'some weeds which grow among our various kinds of wheat, and which have been received, perhaps, originally from Asia along with them. Thus, together with the Barbary wheat, the inhabitants of the south of Europe have sown, for many ages, the plants of Algiers and Tunis. With the wools and cottons of the East, or of Barbary, there are often brought into France the grains of exotic plants, some of which naturalise themselves. Of this I will cite a striking example. There is, at the gate of Montpellier, a meadow set apart for drying foreign wool, *after it has been washed.* There hardly passes a year without foreign plants being found naturalised in this drying-ground. I have gathered there *Centaurea parviflora*, *Psoralea palæstina*, and *Hypericum crispum*.' This fact is not only illustrative of the aid which man lends inadvertently to the propagation of plants, but it also demonstrates the multiplicity of seeds which are borne about in the woolly and hairy coats of wild animals.

The same botanist mentions instances of plants naturalised in seaports by the ballast of ships; and several examples of others which have spread through Europe from botanical gardens, so as to have become more common than many indigenous species. Of these the water-thyme (*Anacharis alsinastrum*) is a striking example. Introduced into this country from America in 1841, it has spread so rapidly that

* De Candolle, Essai Elémen. &c. p. 50. † Quarterly Review, vol. xxx. p. 8.

it has become a nuisance by overrunning ponds and ditches, and impeding the navigation of rivers and canals, in spite of all efforts to eradicate it.

It is scarcely a century, says Linnæus, since the Canadian *Erigeron*, or flea-bane, was brought from America to the botanical garden at Paris; and already the seeds have been carried by the winds so that it is diffused over France, the British Islands, Italy, Sicily, Holland, and Germany.* Several others are mentioned by the Swedish naturalist as having been dispersed by similar means. The common thorn-apple (*Datura Stramonium*), observes Willdenow, now grows as a noxious weed throughout all Europe, with the exception of Sweden, Lapland, and Russia. It came from the East Indies and Abyssinia to us, and was thus universally spread by certain quacks, who used its seeds as an emetic.† The same plant is now abundant throughout the greater part of the United States, along road-sides, and about farm-yards. The yellow monkey-flower, *Mimulus luteus*, a plant from the north-west region of America, has now established itself in various parts of England, and is spreading rapidly.

In hot and ill-cultivated countries, such naturalisations take place more easily. Thus the *Chenopodium ambrosioides*, sown by Mr. Burchell on a point of St. Helena, multiplied so fast in four years as to become one of the commonest weeds in the island, and it has maintained its ground ever since 1845.‡

The most remarkable proof, says De Candolle, of the extent to which man is unconsciously the instrument of dispersing and naturalising species, is found in the fact, that in New Holland, America, and the Cape of Good Hope, the European species exceed in number all the others which have come from any distant regions; so that, in this instance, the influence of man has surpassed that of all the other causes which tend to disperse plants over remote regions. About a fifth of the British flowering plants are supposed to be naturalised species, and a large proportion of them would perish with the discontinuance of agriculture.

* Essay on the Habitable Earth, Amœn. Acad., vol. ii. p. 409.

† Principles of Botany, p. 389.

‡ Ibid.

Although we are but slightly acquainted, as yet, with the extent of our instrumentality in naturalising species, yet the facts ascertained afford no small reason to suspect that the number which we introduce unintentionally exceeds all those transported by design. Nor is it unnatural to suppose that the functions, which the inferior beings extirpated by man once discharged in the economy of nature, should devolve upon the human race. If we drive many birds of passage from different countries, we are probably required to fulfil their office of carrying seeds, eggs of fish, insects, mollusks, and other creatures, to distant regions: if we extirpate quadrupeds, we must replace them not merely as consumers of the animal and vegetable substances which they devoured, but as disseminators of plants, and of the inferior classes of the animal kingdom. I do not mean to insinuate that the very same changes which man brings about, would have taken place by means of the agency of other species, but merely that he supersedes a certain number of agents; and so far as he disperses plants unintentionally, or even against his will, his intervention is strictly analogous to that of the species so extirpated.

I may observe, moreover, that if, at former periods, the animals inhabiting any given district have been partially altered by the extinction of some species, and the introduction of others, a change must have taken place in regard to the particular plants conveyed about with them to foreign countries. As, for example, when one set of migratory birds is substituted for another, the countries from and to which seeds are transported are immediately changed. Vicissitudes, therefore, analogous to those which man has occasioned, may have previously attended the springing up of new relations between species in the vegetable and animal worlds.

It may also be remarked, that if man is the most active agent in enlarging, so also is he in circumscribing, the geographical boundaries of particular plants. He promotes the migration of some, he retards that of other species; so that, while in many respects he appears to be exerting his power to blend and confound the various provinces of indigenous

species, he is, in other ways, instrumental in obstructing the fusion into one group of the inhabitants of contiguous provinces.

Botanists are well aware that garden plants naturalise and diffuse themselves with great facility in comparatively unreclaimed countries, but spread themselves slowly and with difficulty in districts highly cultivated. There are many obvious causes for this difference: by drainage and culture the natural variety of stations is diminished, and those stray individuals by which the passage of a species from one fit station to another is effected, are no sooner detected by the agriculturist than they are uprooted as weeds. The large shrubs and trees, in particular, can scarcely ever escape observation, when they have attained a certain size, and will rarely fail to be cut down if unprofitable.

The same observations are applicable to the interchange of the insects, birds, and quadrupeds of two regions situated like those above alluded to. No beasts of prey are permitted to make their way across the intervening arable tracts. Many birds, and hundreds of insects, which would have found some palatable food amongst the various herbs and trees of the primeval wilderness, are unable to subsist on the olive, the vine, the wheat, and a few trees and grasses favoured by man. In addition, therefore, to his direct intervention, man, in this case, operates indirectly to impede the dissemination of plants, by intercepting the migration of animals, many of which would otherwise have been active in transporting seeds from one province to another.

We shall see in the sequel that species belonging to genera, previously foreign to the province into which they are introduced, often make their way more readily than plants of those genera and species which are indigenous, a fact which has a very important bearing on the theory of the origin of species. It is unfavourable to the doctrine that new species have been specially created in each station as best fitted of all possible organisms to flourish there, while it agrees perfectly with the view that new lands or stations are first colonised by such plants and animals as can gain access

to them without violating the fixed and immutable laws which govern the diffusion of species. Once introduced, they may become adapted by variation and selection to all the peculiar conditions of the new region; but they may still be less fitted for it than some other organisms which may coexist on the globe, and which may hitherto have been prevented by impassable barriers from reaching the same country so as to assert their superiority in the battle of life.

CHAPTER XLI.

INSULAR FLORAS AND FAUNAS CONSIDERED WITH REFERENCE TO THE ORIGIN OF SPECIES.

VOLCANIC ORIGIN AND MIOCENE AGE OF THE ATLANTIC ISLANDS—THEY HAVE NOT BEEN SINCE SUBMERGED, NOR UNITED WITH OTHER ISLANDS—ARGUMENTS AGAINST CONTINENTAL EXTENSION—MAP SHOWING THE GREAT DEPTH OF THE OCEAN BETWEEN THE VOLCANIC ARCHIPELAGOS OF THE NORTH ATLANTIC AND THE MAINLAND—SUBMARINE VOLCANIC ERUPTIONS OF THE PRESENT CENTURY—GENERAL INFERENCES TO BE DEDUCED FROM THE ENDEMIC AND OTHER SPECIES OF ANIMALS AND PLANTS IN THE ATLANTIC ISLANDS—FROM MAMMALIA—FROM BIRDS—FROM INSECTS—FROM PLANTS—FROM LANDSHELLS—SMALL NUMBER OF SPECIES OF LANDSHELLS COMMON TO MADEIRA AND PORTO SANTO—PROPORTION OF SPECIES COMMON TO MADEIRA AND THE DEZERTAS—CONTRAST OF THE TESTACEOUS FAUNA OF THE BRITISH ISLES AND THAT OF THE ATLANTIC ISLANDS—MODE IN WHICH AN OCEANIC ISLAND MIGHT BECOME PEOPLED WITH LANDSHELLS—VARIABILITY OF SPECIES NOT GREATER IN ISLANDS THAN ON CONTINENTS.

In the present chapter I shall consider the characteristic features of the fauna and flora of islands remote from continents. It has been truly said, that the distribution of species in such peculiar situations affords perhaps the severest test by which the theory of Variation and Natural Selection can be tried.

I have already stated that as a general rule, when islands are near a continent, especially if they are only divided from it by a shallow sea, less, for example, than 100 fathoms in depth, their flora and fauna are identical with that of the mainland. But when an island, like Madagascar, is of large size, and is divided from the mainland by a deep channel of the sea several hundred miles wide, the species of quadrupeds differ from those on the continent, although nearly all the genera are the same, while of the other members of the animal and vegetable kingdoms there is a greater or less identity according to the class to which they belong.

If we then go a step farther, and contemplate small islands

far from land and surrounded by a deep ocean, we find that they are remarkable for the number of peculiar species of animals and plants which they contain, even a single island of the same group being sometimes inhabited by many species exclusively belonging to it. Yet even in such localities an affinity can be traced between the insular forms considered as a whole, and those of the nearest continent—a relationship exceeding that which connects them with the fauna and flora of more distant parts of the globe.

Volcanic origin and Miocene age of the Atlantic islands.—I shall refer chiefly to the Madeiras and Canaries as types of oceanic archipelagos, as I have myself visited them and studied their geological structure, without a knowledge of which the speculations and theories of a zoologist or botanist as to the mode in which they may have been peopled with living beings must necessarily be most imperfect. For in the first place we require information as to the period of the past to which the origin of the islands can be traced back, and then we have still to enquire whether they are fragments of a pre-existing continent, or were formed in mid-ocean by volcanic eruptions.

If we find evidence that in the case of these Atlantic islands the latter conclusion is true, we have still to learn whether each of them have continued above water during the whole course of its growth by successive eruptions, or whether it may have undergone oscillations of level, by alternate upheaval and subsidence. To most of these questions we are fortunately able to give satisfactory answers. It may be affirmed that the earliest eruptions took place in that part of the Middle Tertiary period which I have called Upper Miocene. As soon as the first solid lavas raised their heads above water, they were exposed to the action of the waves, and fragments of volcanic rocks were detached and rounded on the shore, and some of them swept into the adjoining depths of the sea, so as to form pebble beds, or conglomerates, or sands and sandstones, in which corals and shells of Miocene species were imbedded. By far the larger number of these species are now extinct. Their fossil remains have been rendered visible to us by their having been

uplifted in various islands to great heights, especially in the Grand Canary, Madeira, and Porto Santo, where they sometimes reach elevations of from 1,500 to 2,000 feet above the level of the sea. The movement of elevation was, I believe, very gradual, and went on during the whole period which witnessed the piling up on these islands of several thousand feet of basaltic and trachytic lavas, just as I have described the gradual rise of the Marine Pliocene strata, which constituted the foundations of Mount Etna, while the volcanic superstructure of the great cone was continually in progress.*

Nowhere could I detect, in any of the Atlantic islands which I visited, any signs of subsidence, or even of the temporary submergence of old terrestrial surfaces. In Madeira there are hundreds of thin horizontal layers of a red-brick colour, dividing those sheets of ancient lava which are seen in the sea-cliffs or in precipices in the interior. They exactly resemble a layer of burnt vegetable mould near Catania, already described (p. 13), as having been overflowed in the year 1669 by a great lava-current, and all of them seem clearly to be similar ancient soils formed by the decomposition of lava or volcanic sand. They bear testimony to the reiterated obliteration and renewal of old habitable surfaces, unaccompanied by any signs of submergence or the intervention of the sea. The movements of upheaval, on the other hand, seem to have been always partial and confined within the limits of the separate islands in which we find the marine strata uplifted. The 100 fathom line is always near to the shore,† and outside of this line the depth of water increases very rapidly, so that it is highly improbable that any of the principal islands were united and afterwards disjoined. Madeira would, indeed, be connected with the Dezertas,‡ if the sea was to sink 100 fathoms (600 feet); but there is no geological reason for presuming that the intervening ridge, over which there is, in one part, more than 400 feet of water, ever formed an unbroken isthmus joining Chão (see map, fig. 143) to the south-eastern extremity of Madeira.

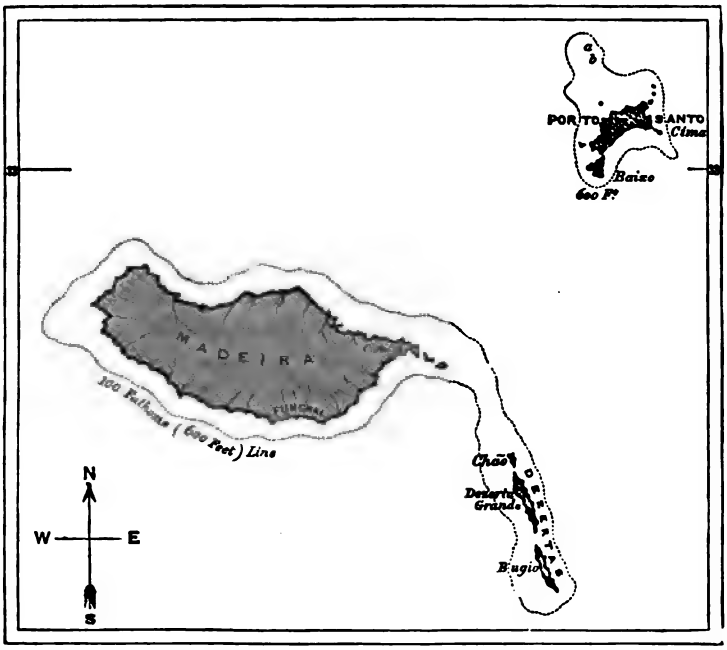
The great antiquity of the Canaries and Madeiras is at-

* Vol. ii. p. 5. † See Map, p. 409. ‡ See Map.

tested by the two-fold evidence of the height and magnitude of the islands themselves, and the age of the fossil organic remains (of Miocene date) already alluded to as having been imbedded in the products of early eruptions.

In Madeira the volcanic accumulations rise to the height of 5,000 feet, and in the Grand Canary to 6,000 feet. The

Fig. 143.



Map of the Madeiran Archipelago.

a. The Styx reef, 72 feet under water.
b. The Falcon reef, 26 feet under water.

highest crater in Teneriffe rises to an elevation of more than 12,000 feet above the sea-level. We know that violent eruptions are usually separated by long intervals of time; and from the history of the Canaries and volcanic archipelagos in general, we may infer that when one island is in a state of unusual volcanic activity, the other adjoining islands enjoy comparative repose. Moreover, in one and the same island, different sets of vents have been in eruption in succession; as,

for example, in Madeira, where the series of cones which now constitutes the highest and central ridge, is not the most ancient, for lavas proceeding from those vents, and flowing southwards, have overwhelmed the products of an older series of eruptions.*

Scarcely any progress has been made as yet in tracing in any of the archipelagos the passage from a Miocene to a recent fauna and flora by aid of fossil remains preserved in volcanic tuff; but Mr. Hartung and I were fortunate enough to discover in 1854 at San Jorge in Madeira, in a deep ravine at the height of 1,000 feet above the sea, a layer of lignite containing impressions of the leaves of forest trees and some ferns. They appear to belong to some part of the Pliocene period, and are certainly of great antiquity, for the numerous beds of lava and layers of volcanic ash piled over them are about 1,100 feet thick. Sir C. F. Bunbury, and after him Professor Heer, have shown that these fossil leaves prove Madeira to have been clothed, at the period when they were imbedded (possibly in the mud at the bottom of an old crater), with evergreens and other laurel-like trees, such as *Laurus* and *Oreodaphne* mixed with species of European genera, together with ferns, such as *Woodwardia*—in fact, with just such forests and such an undergrowth as we now find characteristic of the native vegetation of the island. Some of the species, however, according to Heer, differ from any now living in Madeira. †

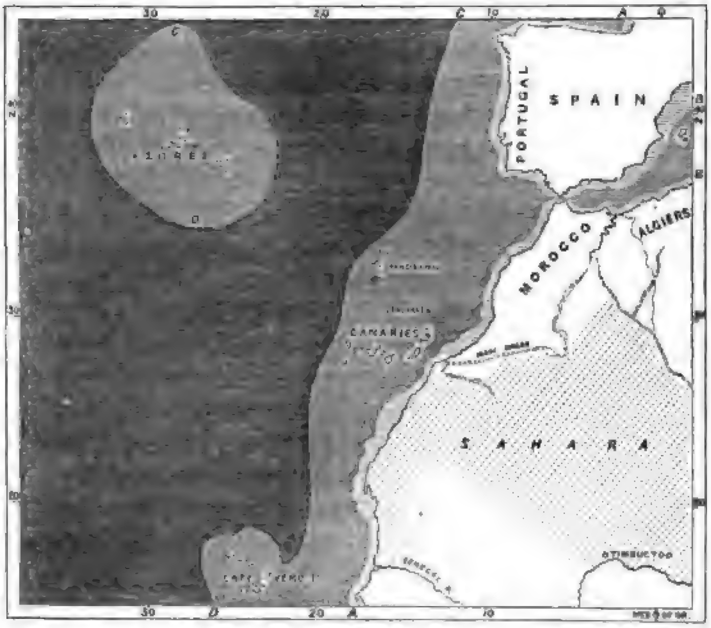
It is a favourite opinion of some naturalists, and one advocated by Edward Forbes, that the Azores, Madeiras, and Canaries are the last remaining fragments of a continuous area of land, which once connected them with the West of Europe and North Africa. In order to explain my reasons for dissenting from this hypothesis, I may refer the reader to the adjoining map, partly based on a chart in Maury's Physical Geography of the Sea, and partly on Admiralty charts, for an analysis of which I am indebted to Mr. T. Saunders. A glance at this map will satisfy the reader that the theory of continental extension involves an amount of change of level

* See 'Lyell's Elements,' p. 639.

† See Bunbury, Geol. Quart. Journ., 1854, vol. x. p. 326, and 'Lyell's Elements,' 6th edit. p. 642, and 'Student's Elements,' p. 516.

so vast, that to assume its occurrence since the close of the Miocene epoch, is quite inconsistent with what we know of the constancy of the position of continents and oceanic basins throughout long geological periods. The Azores, in which the oldest fossiliferous rocks, like those of the Madeiras and Canaries, are of Upper Miocene date, are everywhere surrounded * by a zone of ocean more than 10,000 feet deep. There is, indeed, one line of soundings having a depth of more

Fig. 144.



Map, showing the depth of the ocean between the eastern volcanic archipelagos of the North Atlantic and the Mainland.

The ocean is tinted according to its depth, thus:

From the coastline to a depth of 1,000 feet *lightly*

From 1,000 feet to 10,000 feet . . *darker*

Below 10,000 feet . . . *very darkly*

The lines of 1,000 feet are lettered *A.B.*, and the lines of 10,000 feet *C.D.*

than 15,000 feet between the Azores and Portugal, showing that a land communication would imply, first, the sinking of

* See Map.

a great continental area down to the sea-level, and then a further depression of the same from the sea-level to a depth of from 10,000 to 15,000 feet and upwards, all since the close of the Miocene period. The Madeiran archipelago, it will be seen, is near the line *C D*, which expresses a depth of 10,000 feet, and the same may be said of the western portion of the Canarian archipelago. On the eastern side of this last, the ocean has a depth of several thousand feet, dividing Fuertaventura and Lanzerote from the mainland. The general abruptness of the cliffs of all the Atlantic islands, coupled with the rapid deepening of the sea outside the 100 fathom line, are characters which favour the opinion that each island was formed separately by igneous eruptions in a sea of great depth. No geologist can doubt that the beds of lava and volcanic ash originally sloped down gradually towards the shore, and that the abrupt precipices now so general and often from 1,000 to 2,000 feet in almost perpendicular height facing the Atlantic, have been caused by the undermining action of the waves.

Submarine volcanic eruptions of the present century.—From what we know of the modern history of volcanic action in the basin of the Atlantic, we can be at no loss to conceive the manner in which such groups as the Azores or Canaries originated. I have already mentioned that the foundations of a future archipelago seem now in the act of being laid in the open ocean north-west of Ascension Island.* Here no less than 1,200 miles from the nearest part of Africa, unequivocal signs of submarine eruptions are occasionally witnessed. On this spot, so far out of sight of land, we may expect on some future day that a cone and crater will be built up as was Sabrina in 1811, in the sea off St. Michael's, one of the Azores, or as was Graham's Island, which in 1831† rose up in a deep part of the Mediterranean, thirty miles from the nearest land, the south coast of Sicily. Although both these islands were gradually swept away by the waves, they have left reefs of solid rock in those parts of the sea from which, on some future occasion, a new volcanic cone may arise.

* See above, p. 64. † See above, p. 60.

In November 1867 a submarine volcano burst out in the South Pacific at a point 1,200 geographical miles from New Zealand and 1,800 from Australia, between two of the most easterly islands of the Samoa or Navigator's Group, an archipelago where there had been no tradition of an eruption within the memory of man. This outburst was preceded by numerous shocks of earthquakes. Jets of mud and dense columns of volcanic sand and stones, rising 2,000 feet, and the fearful crash of masses of rock hurled upwards and coming in collision with others which were falling, attested the great volume of ejected matter, which accumulated in the bed of the ocean, although there was no permanent protrusion of a new volcano above its level.

General inferences to be deduced from the endemic and other species of animals and plants in the Atlantic Islands.—Whether therefore we consider the composition of the rocks and structure of the Atlantic islands, or their comparatively modern origin, or the vast depth and extent of the sea which separates them from the nearest continent, all these characters conspire to lead to the belief that they have been formed in mid-ocean by volcanic agency; and we shall find, if I mistake not, that the geographical distribution of the species, both of animals and plants, contained in them is far more in accordance with such an hypothesis than with that of continental extension. If, when the first islands were formed, the earliest colonists consisted of plants and animals which arrived as waifs and strays from the nearest land, they must have consisted of species which inhabited Europe and the North of Africa in Upper Miocene times. Fortunately we have made considerable progress in ascertaining what was the character of the fauna and flora of that epoch, differing widely as it did from that now existing in the same regions. We know, for example, that the Miocene flora of Europe had a strong generic affinity to the vegetation now characterising North America, much greater than to that of any other part of the globe in our own period; so that, if we find American forms in these Atlantic islands, it does not violate the general law that the animate creation in oceanic archipelagos bears always most resem-

blance to that of the nearest adjoining mainland, for these American forms are doubtless the remnants of a flora derived from an ancient and adjoining Miocene continent. But we must also remember that the Miocene fauna and flora of Europe gradually gave place to another of Pliocene date, and all these fluctuations in the animate world must have made themselves felt in the oceanic islands in which the successive destruction and renovation by volcanic action of the terrestrial surfaces would facilitate the settling in them of new species brought to them by the winds, marine currents, and various agents of transport, organic and inorganic. New sheets of lava would in particular weaken the barrier which preoccupancy opposes to new colonists; for the melted matter first annihilates every living thing over the strip of land, more or less broad, which extends from the volcanic orifice to the sea-coast, and then, after many years, when the lava has decomposed, it affords a fresh and virgin soil on which new immigrants may settle. Volcanic ejections and movements of upheaval, by causing perpetual variations in the surface-level of each island above the sea, would also promote fluctuations in the fauna and flora. That low portion of Africa which is marked in our map (fig. 144, p. 411), as the Sahara, was probably under water during the Miocene period. It is also possible that some volcanic islands may, during or since the Miocene era, have been formed and again destroyed within the area embraced in this map. They may have played an important part in promoting the interchange of species between different archipelagos, or between them and the continent.

It will be seen that at present, about half way between Madeira and the Canaries, there are some isolated rocks called the Salvages, which attain a height of 100 feet above the sea. The largest of them, which, like the rest, is uninhabited by man, is about a mile long. They rise from a deep ocean, and their steep cliffs show that they have been much reduced in size by the waves. The plants, insects, and land-shells found upon them belong in part to those peculiar types called 'Atlantic,' probably the relics of a Miocene fauna and flora.

The foregoing remarks on the geography and geology of the Atlantic islands are indispensable to a reader who would follow us in our speculations on the manner in which they may have become peopled with the animals and plants now inhabiting them. The absence or abundance of each class, the number of species common to the nearest continent, the range, whether limited or extensive, of each species through different islands or through different archipelagos, may throw light on the question whether species have been independently created, or whether they are modifications of pre-existing forms, the products of Variation and Natural Selection.

Mammalia.—The first great fact for which we have to account, is the entire absence of all indigenous Mammalia except bats. Palma, one of the Canaries, is inhabited by an indigenous bat, the progenitors of which may have migrated to that island in Miocene or Pliocene times.

When we have travelled over large and fertile islands, thirty miles or more in diameter, such as the Grand Canary and Teneriffe, and have seen how many domestic animals, such as camels, horses, asses, dogs, sheep and pigs, they now support, we cannot but feel amazed that not even the smaller wild animals, such as squirrels, field-mice, and weasels, should be met with in a wild state. The reader may ask how such quadrupeds could have reached an island like Madeira, more than 360 miles from the nearest mainland; but such a question at once implies the admission, that an arbitrary exertion of creative power does not give origin to Mammalia in every region where conditions favourable to their support may happen to exist.

It was long ago remarked by Dr. Prichard,* that among the various groups of fertile islands in the Pacific, no quadrupeds, with the exception of a few bats, have been met with, which might not be supposed, like the dog, the hog, and the rat, to have been conveyed thither from New Guinea by the natives in canoes. What is more extraordinary, even the large island of New Zealand, when first explored by Europeans, was found to be destitute of indigenous Mammalia,

* Prichard, Phys. Hist. of Mankind, vol. i. p. 75.

except one species of rat and two bats, said to be different from any found elsewhere. Bats have been seen wandering by day far over the Atlantic Ocean, and two North American species are known to visit the Bermudas at the distance of 600 miles from the mainland.* Mr. Darwin has therefore emphatically dwelt on the absence of Mammalia in islands far from continents, as strongly confirmatory of his theory of the origin of all species by descent from pre-existing closely allied species. The absence of Mammalia also supplies us with an argument against the doctrine of continental extension. Had a large tract of land stretching from Europe to the Atlantic islands been gradually submerged, so that at last no vestige of it remained above water, except the tops of certain volcanic mountains, the Mammalia would have retreated into such spots, for the smaller species at least might have found subsistence there. It has been suggested by the advocates of continental extension, that if Java should sink down several thousand feet, no land would be left except the summits of a series of lofty volcanic cones, round which there would be everywhere a deep ocean. But these same cones, as we have seen (p. 362), would each of them be inhabited by its peculiar Mydaus, and no doubt other species of Mammalia would take refuge there. Had any quadrupeds been able to swim to the Azores, Madeiras, or Canaries in the Miocene epoch, there is no ground for supposing that their descendants would not still survive; for, as before stated, each island seems during its whole growth to have afforded a habitable surface to terrestrial beings.

The rapid multiplication of goats when allowed to run wild in St. Helena, and of both goats and dogs in Juan Fernandez when introduced by the Spaniards, and of rabbits in Porto Santo, from a single brood imported there in 1418, proves the fitness of small islands to maintain wild quadrupeds, if they can once make their way into them.

The total dearth of Batrachians (frogs, toads, and newts), has also been pointed out by Darwin, as a characteristic of oceanic islands; yet he remarks that frogs, when taken to Madeira, the Azores, and Mauritius, have thriven to such a

* Origin of Species, p. 469; 6th edit. p. 351.

degree as to become a nuisance. If their spawn were carried down by a river to the sea, it would at once be destroyed by the salt water, as has been ascertained by experiment, and it is not of a nature to adhere to the feet of birds, as Mr. Darwin has found by observation.

A strong current which flows from the north, and passes between the Atlantic archipelagos and the mainland, may perhaps have prevented Mammalia and reptiles from reaching even the Canaries, one of which, Fuertaventura, is now only fifty miles from Africa, though possibly it was more distant when the Sahara was still under water. The same current may have prevented canoes from being drifted to Madeira, which is so isolated in mid-ocean, and on the shores of which no human being is believed to have ever landed until the year 1419. Madeira now supports a population of about 80,000 souls, and when we consider the great beauty and fertility of the island, and that it has existed ever since the Miocene epoch, we are not merely called upon to explain the absence of inferior animals, but why, if we adopt the theory of special creation, no race of mankind was formed expressly to inhabit such a paradise.

Birds.—For the same reason that bats, being provided with wings, form an exception to the general rule of the absence of Mammalia in oceanic islands, so we might expect that the feathered race would, of all classes of Vertebrata, be most fully represented. Accordingly we not only find this to be the case, but what is still more significant, as bearing on the theory of transmutation, almost all the birds in the Atlantic islands are absolutely identical in species with those of the nearest mainland. Thus in the Canaries and Madeiras, all the species except three or four are European. Of the 99 Madeiran species, there is only one peculiar to that island, and it is closely related to a European form; the other two non-European species are common to the Canaries. In the Azores, there are only two peculiar species, out of 51, and these two, a chaffinch and a bullfinch, are closely allied to European and North African birds.*

* Ibis, vol. ii. 1866, new series, p. 88.

We learn from Mr. Du Cane Godman, as before cited (p. 368), that every winter some birds are driven by violent gales over 1,000 miles of ocean from England to the Azores. The same observer informs us that the species are most numerous in the easternmost islands, and that the number diminishes rapidly as we examine those lying farther west, showing that the wearied and hungry voyagers drop down on the first land they discern. It is only by this frequent arrival of new-comers that we can explain the specific identity of the insular and continental fauna, the tendency to variation and indefinite divergence being checked in the manner explained at p. 322, by the absorption of the insular into the continental types, with which they are continually crossed. There are no American birds in the Azores, which cannot be entirely explained by the greater distance of that continent, because no less than sixty species are known to have crossed the Atlantic as stragglers, and to have reached the British Islands. The fact simply proves that strong winds blowing continuously in the right direction, are indispensable to enable birds to colonise remote islands.

The Bermudas, which are 700 miles from the coasts of America, are stocked with *species* all belonging to that continent. Of three European stragglers mentioned by Baird, two are common to Greenland, and may have come from the north, Newfoundland having served as an intermediate halting-place; and the third, our common sky-lark, a rare and occasional visitor, is so often carried in ships to America, that it may perhaps sometimes escape from a cage, and alight on the first land which presents itself.

The number of days for which land-birds can fast would more than suffice for their flight from Europe or even from America to the Azores. Mr. Bartlett informs me that a partridge sent from the London Zoological Gardens to the country remained accidentally in the box in which it was enclosed for five days without food or water; when discovered, it was alive, and being fed was soon restored to its usual vigour.

The birds of the volcanic archipelago of the Galapagos present in some respects a contrast to those of the Atlantic

islands; for although the distance from the nearest mainland is scarcely more than half that which separates the Azores from Europe, four-fifths of the land-birds are of species found nowhere else in the world. Out of twenty-six species, all but three or four are peculiar to these islands, at the same time that the whole of them are of South American types. What is still more worthy of note, several of these land-birds are peculiar to a single island of the group.* To explain this we may suppose that continuous gales have rarely blown from South America to the Galapagos since these islands first lifted their heads above the waves, and for this reason stragglers have only arrived after long intervals, some on one island, and some on another. Once established, they have remained isolated, without communication with birds of the parent stock on the South American mainland, or with settlers of the same stock on other parts of the archipelago. On this subject Mr. Godman remarks, that while in the Azores, winds are constantly blowing from all points of the compass, so that land-birds are carried during storms from one island to another, in the Galapagos there are no such violent gales, but usually uninterrupted calms. He also adds, that while the marine currents in the Azores flow in varying directions, those of the Galapagos are strong, and always in the same direction. As to the web-footed birds or waders of the Galapagos, Mr. Darwin found that out of 11 species all except two consist of species common to the nearest continent.† This fact agrees well with the very wide range of this order of birds in all parts of the world, and is in accordance with their migratory habits. The relationship of the birds of the Atlantic islands to those of Europe and North Africa is nearly the same as that usually observed in a continuous continent. A few exceptional and peculiar types may in some cases have arisen from Variation and Natural Selection, since they first arrived, and some of them may perhaps be the descendants of Miocene species or genera which have died out in the mother continent.

Insects.—The insects of Madeira, the Salvages, and the

* Darwin, Origin of Species, p. 465. † Ibid.

Canaries, unlike the birds, exhibit a large proportion of indigenous species, and a great many genera peculiar to the Atlantic islands, represented in each separate archipelago by distinct species. Mr. T. V. Wollaston, in his 'Coleoptera Atlantidum,' has described no less than 1,449 species of beetles belonging to the three groups of islands above mentioned. Nearly all of these have been collected by himself, and of the whole number more than 1,000 are of species hitherto unknown as inhabiting any other region, although there is no doubt that a great many of them will hereafter be discovered in lands bordering the Mediterranean. The distinctness of the fauna of different archipelagos is shown by the fact that out of 1,007 species obtained from the Canaries, and 661 from the Madeiras, only 238 are common to the two groups. Even of these it is suspected that the larger number have been introduced by man, and it is quite certain that 38 species have been so imported in very modern times.

Nearly every detached island adds some distinct species or marked variety to the general list, and one half of the 24 species found on the rocks called the Salvages, before mentioned, are peculiar, some of them belonging to those forms which have been called Atlantic types. 'If,' says Wollaston, 'we exclude those beetles which have probably been naturalised by human agency, there are marvellously few species which permeate the whole of the archipelagos, yet with few exceptions the genera are common to the whole.' Among the dominant forms the weevils, or *Curculionidæ*, preponderate greatly, and certain families of them are of essentially Atlantic types. No less than 50 species and varieties feed exclusively on the Euphorbias which are so abundant and diversified in form in the Canaries. Some fossil plants of the genus *Euphorbia* occur in the Miocene strata of Œninghen in Europe, and the parent stock both of these plants and of the Atlantic *Curculionidæ* may perhaps have been derived from the old Miocene continent. It has been already proved, by the researches of Heer and others, that the Miocene Coleopterous Fauna of Central Europe was actually richer than that now living in the same latitudes;* so that we

* 'Lyell's Elements of Geology,' p. 254; 'Student's Elements,' p. 198.

may well imagine that the various means of transport already alluded to (p. 382), by which insects are often carried seaward, may have been the means of introducing into the oceanic islands some of the progenitors of the present insular fauna.

The inferior facilities enjoyed by insects as compared to birds of crossing the sea, afford probably the true explanation of the marked difference in the relationship of the two faunas to that of the mother continent, and also of the comparatively small number of insects common to different islands of the same group. In proportion as the interchange of species is an event of rare occurrence, Variation and Natural Selection will be efficacious in forming distinct races in separate islands.

A recent examination of the beetles collected in the Azores by Mr. Godman, and described by Mr. Crotch,* shows that that archipelago presents phenomena analogous to those of the Canaries and Madeiras, although the proportion of Atlantic types is smaller, and the living European forms more predominant. This somewhat anomalous state of things may perhaps be accounted for by the fact, that although the Azores are so much farther from Europe than Madeira and the Canaries, yet they are situated in a much stormier latitude, and thus receive waifs and strays more frequently.

Plants.—Dr. Hooker, in his admirable essay on Insular Floras, † remarks that in Madeira, besides the numerous cultivated plants which have been introduced by man, and the poppies, fumitories, groundsels, and other weeds which he has brought with him unintentionally, there are other native varieties of European species, and sometimes representative genera, which indicate a relationship to the nearest continent. He also observes that whereas we find on ascending mountains in Great Britain or on the continent of Europe, from the height of 2,000 feet and upwards, species proper to more northern latitudes, and differing from those flourishing at lower levels, we do not meet with any

* Azorean Coleoptera, Zool. Proc. 1867; pt. ii. p. 349.

† Lecture to Brit. Assoc. Nottingham, 1866; Gardener's Chronicle, 1867.

such boreal forms in Madeira even at the height of 4,000 feet. The species become fewer as we ascend, but they continue to be the same as those which flourish at inferior elevations. Had the theory of continental extension been true, we might have expected the Atlantic islands to have borrowed their upland flora from higher latitudes during the Glacial period.

A botanist, wholly ignorant of the plants which lived on the continent of Europe in Miocene times when the first volcanos were beginning their eruptions in the Canaries, Madeiras, and Azores, would be in no small degree perplexed at the presence in these archipelagos of such Atlantic types as Clethra and Persea, of which living representatives exist in no part of the world nearer than the continent of North America. It would seem to be a violation of the general law according to which the organic productions of islands bear most resemblance to those of the nearest continent. But fortunately the labours of Unger, Heer, and Göppert on the fossil botany of the tertiary strata have shown us that Europe, when the Atlantic volcanos first reared their crests above the waves, was covered with an exceedingly rich vegetation.

No less than 900 species of these fossil plants have been detected in the strata of a single locality at Œninghen in Switzerland.* The most conspicuous feature, says Heer, in this ancient flora, is the large number of genera of plants now peculiar to America; whereas those having European affinities only hold the second rank, those of Asia the third, of Africa the fourth, and those of Australia the fifth. Among the prevailing American forms are Clethra and Persea, above alluded to, genera common to Madeira, the Canaries, and Azores. Regarded as relics of a Miocene flora, they are just such forms as we should naturally expect to have come from the adjoining Miocene continent. Another plant of a singularly aberrant form, and which we may well imagine to be the last survivor of a Miocene type, is the *Monizia edulis*, belonging to a genus which has now no representative else-

* For a brief sketch of the Miocene flora and fauna, see 'Lyell's Elements,' 6th ed. chap. xv.; and Student's Elements, p. 186 et seq.

where in the world. This conspicuous shrub is an umbelliferous plant with a stem like an inverted elephant's trunk, crowned with a huge tuft of parsley-like foliage. A fine specimen of it may now (1867) be seen growing in the greenhouse of the Botanical Garden at Kew. It is peculiar to one of the rocky islands of the Dezertas,* where it probably owes its preservation to the exceptional conditions which it has there enjoyed cut off from all communication with other islands, into which new colonists, both of the animal and vegetable worlds, have been able more freely to penetrate.

Dr. Hooker reminds us that the extinction of so many species and of some genera which flourished in the Miocene period in Europe, is fully accounted for by the great change of climate which the temperate latitudes of the northern hemisphere experienced in Pliocene and Glacial times. The old subtropical species, which had long flourished in Central Europe and in the regions bordering the Mediterranean, gave way before a more northern flora, but many plants and not a few of the insects, which were extirpated on the continent, may well have survived in oceanic islands which enjoyed a milder and more equable temperature. To this source we may probably refer those peculiar 'Atlantic types' above alluded to, which pervade all the archipelagos. We are informed by Dr. Hooker that the seeds of the West Indian bean-like climber Entada were floated to the Azores 3,000 miles by the Gulf-stream. These seeds, after such long immersion in salt water, although they could not stand the climate of the Azores, germinated in the Garden at Kew; from which fact we learn how easily seeds of the Miocene period may have been carried uninjured by currents from the Mediterranean region to any one of the Atlantic islands, as none of them are so far from Europe as are the Azores from the West Indies. But it is probably to birds more than to marine currents that new islands owe the plants which clothe them. We have already seen (p. 394) how many seeds which have been swallowed by birds and ejected in their dung, germinate freely, and these, if carried by a land-bird driven to a new volcanic island,

* See Map, fig. 143, p. 409.

would soon cover the unoccupied ground, until other species brought by a similar mode of transport came to dispute their monopoly.

It is not easy to conjecture how many different modes of transport nature may have employed in peopling some Atlantic islands. Even icebergs may have played their part in carrying plants to the Azores in the Glacial period, for they are now sometimes floated to latitudes farther south than that archipelago, as we have already stated (Vol. I. p. 249). Mr. Hartung found fragments of rock in the Azores which he regarded as erratics of iceborne origin. When, indeed, we consider all the changes in climate, and in the direction of winds and currents, and in the species of birds which have occurred in the lapse of millions of years since the Miocene epoch, to say nothing of the incessant transformations undergone by the volcanic islands themselves, we must feel that the colonisation of the several archipelagos has been the result of such a complexity of causes and conditions, that the distribution of species is not more anomalous or capricious in its character than we might reasonably have anticipated. If we find a plant or animal peculiar to a single island, we may suppose it to have been first brought there as a straggler from the adjoining continent, and it may never have been able to spread to any other island; or it may have had a wider range until dispossessed of most of its former stations by new intruders, or by volcanic eruptions; or lastly, the parent stock may still flourish in some one of the islands or archipelagos, but the descendants may have gone on diverging from the original type, until, in the lapse of thousands of generations, the amount of difference may be of specific value. When it is said that the Atlantic types, whether of plants or insects, are common to the Azores, Madeiras, and Canaries, it is only the genera which are spoken of, for the species are almost always distinct in each archipelago.

Mr. Darwin had said in his 'Origin of Species,' that we probably still remain ignorant of many means of transoceanic migration which will one day be discovered.' These anticipations have been singularly verified even since 1866, when

this opinion was advanced in the fourth edition of his celebrated work.* Some singular illustrations of the truth of this opinion have since been obtained. Hearing that many new plants had been observed to spring up in Southern Africa in districts which had been invaded by locusts, Mr. Darwin procured from a correspondent, Mr. Weale, residing in Natal, a small packet of dry locust dung, weighing less than half an ounce. Seeds were extracted from the middle of several pellets, and their true nature ascertained by dissection, and others were sown, which, when they had germinated, produced no less than seven individuals belonging to at least two kinds of grasses. A locust of the migratory species blown from the coast of Africa was taken on one occasion by Mr. Darwin himself when at sea, at a distance of 370 miles from the nearest land, or somewhat farther than is Madeira from Africa. The same naturalist observed in 1867 some mud adhering firmly to the foot of a woodcock, which weighed when dry nine grains. He extracted from it the seed of the *Juncus bufoni*, which germinated. This fact throws much light on the colonisation of new islands by plants, for of all families even of wading birds the woodcocks are perhaps the most migratory, and there is scarcely a remote island which they do not sometimes reach.

Mr. Lowe informs me that when he was in Madeira in 1844 he witnessed the arrival at Funchal of a flight of locusts, which came probably from Africa. For three days they whirled slowly in a circle or ellipse of about five miles diameter round the town, alighting on the trees at night and continuing their flight by day. They do not seem to have consumed much of the vegetation, and when caught appeared torpid and inactive. Their length was about three inches, and they were as numerous as the flakes of snow in a snowstorm, a telescope directed upwards not enabling the eye to reach the upper limits of the swarm. After two or three days they disappeared, and vast shoals of them were seen afterwards floating on the surface of the sea. It is remarkable that they made no permanent settlement upon

* Chap. xi. 4th ed. p. 433. 1866.

the island, the locust not being one of the Madeiran insects, nor is it known that they introduced any new plants in their dung; but as probably more than one migratory swarm has visited the island again and again, perhaps at distant intervals since it originated, some of the species of the insular flora may have been derived from this source.

When we compare the flora of any one of the Atlantic archipelagos—that of the Madeiras for example—with that of the British Islands, the difference in the number of indigenous species and in the proportion of plants common to the nearest continent is truly marvellous. In the Madeiras there are hundreds of indigenous species, although the entire flora is not half so numerous as the British, while, on the other hand, all the British plants are species common to the continent of Europe, except two, the *Spiranthes gemmipara*, which occurs on the north-west side of Bantry Bay in Ireland, and is found nowhere else on this side of the Atlantic, and a North American water-plant, *Eriocaulon septangulare*.

Landshells.—I have reserved to the last my comments on the landshells, as their geographical distribution in the Atlantic islands is more singular and instructive than that of any other class of living beings. In the Madeiran archipelago especially, as was long ago pointed out by the Rev. R. T. Lowe, every island has its distinct species, and the whole fauna differs almost entirely from that of Europe and Africa. Moreover, it is when we contemplate these air-breathing mollusks that we find the contrast between the Atlantic and British islands to have reached its climax; for in Great Britain no one of the different islands is characterised by peculiar species, and the insular and adjoining continental faunas are the same.

Mr. Lowe, in the year 1834, described 71 species of landshells of the genera *Helix*, *Bulimus*, *Achatina*, &c., from the Madeiran archipelago, 44 of which were new. He then stated that but few of these were common to the Canaries, and, what was still more astonishing, only two were common to the islands of Madeira and Porto Santo, divided by a sea only 30 miles wide. Since his memoir was published his own further investigations, and those of Mr. Wollaston

and others, have augmented the list of species, and taught us that some few of those before known had a wider range than was at first supposed; but notwithstanding these additions to our knowledge, the general conclusions announced in 1834 hold good, or are even rendered more striking. The instruction derived from this fauna is greatly enhanced by the occurrence, both in Madeira and in Porto Santo, of large assemblages of fossil shells which reveal to us the state of this part of the animal creation in the Newer Pliocene period. Some few of the fossil species are extinct, but most of them are the same as those now inhabiting Madeira and Porto Santo respectively; consequently the two ancient groups of shells are as dissimilar as are the two recent ones. From this we learn that in the Newer Pliocene period the two islands must have been disjoined, as they are now. It is also clear that at that period neither island was united with the continent of Europe; for scarcely any of the fossil species are European, and the absence of these confirms the general opinion of naturalists that almost all the species now living in this archipelago and common to the continent have been introduced by man since the beginning of the fifteenth century. During my short stay in Madeira there were found in the earth of a single flower-pot in which a garden plant had been sent from Lisbon no less than three species of Portuguese snails (Helices), showing us how unconsciously the horticulturist is busied in alloying the purity of the native fauna. Most of the European shells have been found in the gardens of Funchal, from which principal town as from a centre they radiate for greater or less distances.

At the time of my visit in 1854 the known living species of Madeira proper, excluding the modern intruders above alluded to, amounted to 56, and those of Porto Santo to 42; only 12 of the whole being common to both islands; and, what is of no small significance, even some of these 12 being represented in the two islands by distinct varieties. In truth, the discordance is more like that of two of the six great zoological provinces of the globe before described (p. 337), than of two islands of the same province in sight of each other.

If we then refer to the fossil groups, we find 36 species in Madeira and 35 in Porto Santo, only 8 being common to the two islands, and 5 of these 8 being represented by distinct varieties in each island respectively. It was to be expected that as Porto Santo is much less cultivated than Madeira, and has only a small human population, the fossil and living species should agree much more with each other than do those of Madeira; and the fact that they do so encourages us to reject as spurious or as modern interlopers those landshells now living in Madeira which are missing in the fossil group of that island. The fossils occur at Caniçal near the eastern extremity of Madeira,* in prodigious numbers, imbedded in a superficial deposit of calcareous sand and mud. Among the most common is a conspicuous species of an unusual form named *Helix delphinula* (from its resemblance to the marine genus *Delphinula*), which has entirely disappeared from the Atlantic islands. Another smaller but very characteristic shell, *Helix tiarella*, must have swarmed in the Newer Pliocene period, but it has now become so extremely rare that for a long time it was supposed to be extinct, until a few surviving individuals were detected by Mr. Wollaston, in 1855, at a great height on some precipitous and nearly inaccessible rocks in the interior of Madeira. Two species of Achatina and two of Pupa, also fossil at Caniçal, are supposed to have disappeared from the living creation, but as they are of small dimensions they may possibly have been overlooked, although, if extant, they must have become very scarce.

In the shelly sand of Porto Santo a conspicuous shell, *Helix Lowei*, is very abundant. It is of so large a size that it could hardly have escaped detection if it still existed on either of the principal islands, but lately a few individuals of this species have been detected on the rock called Ilheo di Cima off Porto Santo.† By some conchologists *Helix Lowei* is regarded as a gigantic variety of the living *H. Porto sanctana*, which also occurs fossil in the same sands. If this opinion be correct, it offers by no means the only example in

* See Map, fig. 143, p. 409. † Ibid.

the fauna of this archipelago of the same distinct races being found both fossil and recent, and in both cases without any intermediate varieties. One of the two forms may possibly represent the parent stock, and the other the extreme of divergence. There must once have existed, according to the theory of Natural Selection, all the transitional forms between the two extremes. But these forms may have died out for want of favourable conditions, or may have been absorbed into one or other of the extremes, which last may be able to maintain their ground on the principle before alluded to (p. 320), according to which more plants or animals find support in a limited area if they are of many different genera than if they all belong to one genus. There are however in the Madeiran archipelago some polymorphous species, such as *Helix polymorpha*, in which the transitional links between the extremes are not missing, and they remind us of the varieties of the English brambles and roses; but such cases are the exception to the rule, for reasons to be explained in the next chapter.

I have alluded to *Helix tiarella* in Madeira; an allied representative of the same peculiar form, *H. coronata*, abounds in a fossil state in Porto Santo, and is also still living in that island, though it is rare. Another, or third closely allied species, *H. coronula*, was first found fossil in Bugio, one of the Dezertas, and it probably still exists on some part of those inaccessible rocks, for a few living individuals have lately been found on the nearest adjoining coast of Madeira. They may supply an example of the smaller island having yielded one of its indigenous species to Madeira; for the absence of this shell among the fossils of Caniçal seems to imply that it has only recently gained access to Madeira proper. These three distinct though kindred forms of a peculiar division of the Helicidæ belonging to Madeira, Porto Santo, and the Dezertas remind us of the representative species of some genera found in Asia, Europe, and America.

Having alluded to the Dezertas, I may add that 19 species of landshells have been found on them, 12 of which, or about two-thirds of the whole, are common to Madeira, and only 5 to Porto Santo. The nearer affinity of the fauna to

Madeira was to be expected, not only because of its greater proximity, but because, as will be seen by our map, Madeira and the Dezertas stand within the same 100 fathom line, and the channel between them may once have been narrower, although there is no reason for believing that the land was ever continuous, or even that Chão, Dezerta Grande, and Bugio were ever united; for each of these rocks has some species of shells as well as some varieties peculiar to itself. It is worth remarking, as showing the limited range of species when the whole archipelago is considered, that there are only two species of landshells common to all the three faunas of Madeira, the Dezertas, and Porto Santo.

The antiquity of the fossils of Madeira and Porto Santo is unmistakable, although they are more modern than the newest lava streams; for to say nothing of the time required to annihilate several species and greatly to alter the relative numbers of others, there are proofs of local geographical changes of subsequent date. Since the accumulation of the volcanic sand and mud, in which the landshells are enveloped, there has been much undermining of the sea-cliffs, both in the narrow promontory in which Caniçal is situated and on the northern coast of Porto Santo. Some of the shelly formation of the last-mentioned island consists of sand-dunes which have been cut off abruptly in the vertical cliffs, and must once have extended farther in a seaward direction. The whole island, indeed, of Porto Santo has suffered great denudation, and some rocks indicated by the letters *a b* in our map (p. 409), one of them called the Falcon, now covered by only 26 feet of water, and the other the Styx by 72 feet, may perhaps mark the site of isolated volcanic cones which once rose above the sea-level. But that the whole space within the 100 fathom line * was ever continuous land, I think improbable. Such an extension would give to Porto Santo five times its present dimensions. The proportion of extinct species as compared to the living ones in Madeira and Porto Santo is about 8 per cent., which may perhaps be slightly diminished by the future discovery of

* See Map, fig. 143, p. 409.

some of the smaller species; but the real discordance between the ancient and modern fauna will never disappear, for it is even greater than is expressed by the numerical statements above given, some species formerly most dominant being now very feebly represented, and some fossil races as well as species having become extinct.

The landshells of the Canaries, when we exclude those which have probably been introduced by man, are very distinct from those of Madeira. The different islands in the Canaries have more species in common than the Madeiras, but this fusion may be partly owing to the remote and unknown period at which the aboriginal inhabitants, the Guanchos, settled there.

Contrast of the testaceous fauna of the British isles and that of the Atlantic islands.—I shall now revert to the extraordinary contrast between the distribution of landshells in the Atlantic and British islands. If a curved line be drawn from the Azores through Madeira to the Canaries, its length would be about 750 miles, or about equal to a line drawn from the Shetland islands through Scotland and England to the Scilly islands. The British archipelago contains more than 200 inhabited islands, when we include the Shetlands, Orkneys, Hebrides, and others. In all of these the landshells are the same, whereas in the Atlantic archipelagos it is not only the principal or habitable islands, but almost every uninhabited rock off the coast, which supplies the conchologist with peculiar species or varieties. In the British area, it would seem at first sight, as if the land-snails had never had any difficulty in crossing the sea, whereas in the Atlantic archipelagos the narrowest marine channels have formed in most cases impassable barriers. The Scilly islands are as far from Cornwall as is Madeira from Porto Santo, yet in them the conchologist obtains no distinct species, nor even any marked races, whereas, on crossing from Madeira to Porto Santo, he finds four-fifths of the species different, besides some peculiar races, even of those shells which are common to the two sides of the channel. It may, no doubt, be said that the southern parts of England display a richer fauna, and contain certain species (about eight), which do not range

farther northwards than Yorkshire. These are: *Helix pomatia*, *H. carthusiana*, *H. revelata*, *H. Pisana*, *H. obvoluta*, *Bulimus montanus*, *Clausilia Rolphii*, and *C. biplicata*. It is more difficult to name species which are peculiar to the north, *Vertigo alpestris* affording perhaps a solitary example.*

In what manner, then, can we explain or refer to one and the same law of distribution the apparently ncongruous phenomena exhibited in the two regions above compared? Some zoologists who have been struck with the unusual number of endemic species and marked varieties observed in oceanic islands, have suggested that the terrestrial mollusca must be more variable than other classes of the animal kingdom. But this idea is wholly inadmissible, for we need go no farther than the fossil faunas of Madeira and Porto Santo, above alluded to, to prove the remarkable constancy and persistency of form of the genera *Helix*, *Pupa*, *Achatina*, and *Clausilia*, from the Newer Pliocene era to our own times. To solve the enigma we must appeal to the immense difference in the lapse of time, during which the islands of the British and those of the Atlantic archipelagos have remained separate from each other and from the nearest continents. In the one case there has been everywhere a land communication between every part of the archipelago since the commencement of the Glacial Period, when the species of marine and terrestrial testacea were everywhere the same as they are now; in the other there has been no land communication since the Miocene epoch, when the whole fauna and flora of the globe bore but a distant resemblance to those now established. Our map (p. 409) will satisfy the reader, that if the bed of the Atlantic were everywhere uplifted 100 fathoms, all the principal archipelagos and islands would remain as disconnected as they are now, whereas we know that a similar upward movement would unite every one of the 200 British islands with each other and with the continent.† Indeed, nearly all of them would be joined to the mainland and to each other with a change of level of less than 400 feet. That there have been great

* See Mr. J. Gwyn Jeffreys, British Conchology, 1866–67.

† See 'Antiquity of Man,' by the author, Map, fig. 41, p. 279.

movements of oscillation in the British area since the Glacial period is proved by independent geological evidence, whereas there are no signs, as before stated, of any general movements of like magnitude in the Atlantic area, but only here and there some evidence of partial upheaval.

I have already remarked that had Porto Santo been united with Madeira proper in the Newer Pliocene period, the two fossil faunas would have been fused together, instead of being as different as are the living native shells of the two islands. In Great Britain, also; we have a fossil fauna of terrestrial shells associated with the bones of the Mammoth and other extinct mammalia in ancient drift; and this enables us to carry back the comparison of the Atlantic and British archipelagos one step farther. We recognise in the British fossils the same uniformity, or wide range of species, as in the actual or recent fauna. No less than 48 species of fossil landshells were collected by the late Mr. John Brown from the Post-Pliocene drift of Copford in Essex, and with the exception of two Helices, (which still survive on the continent,) all are of living British species. But if England had been submerged a few hundred feet, and divided into islands, even since the Pliocene period, we might have expected the shells associated with extinct quadrupeds in different counties to display some marked want of agreement in species and varieties. There is however no such contrast. If, for example, we compare the landshells of the Wiltshire drift, near Salisbury, of the age of the Mammoth, with those of Essex before mentioned, places twice as far apart as are Madeira and Porto Santo, they exhibit no difference whatever in the species of fossil landshells. From this fact we may infer that although the British area has been partially submerged since the commencement of the Glacial period, yet its normal state has been a continental one.

Mode in which an oceanic island might become peopled with landshells.—The reader may well ask, if Madeira and Porto Santo have made so little progress in interchanging their respective species of landshells in the course of that vast lapse of ages which has occurred since the Newer Pliocene period, how could any of the Atlantic archipelagos ever have

become peopled by migration from Europe or Africa? The enigma is certainly perplexing, and we must assume that the arrival of landshells, as waifs and strays from a continent, is an exceedingly rare event. It has been suggested that birds may transport across the sea the eggs of these mollusks in mud attached to their feet. But if so, why have the birds which fly freely across the channel, only 30 miles wide, between Madeira and Porto Santo, allowed the fauna of these two islands to remain so distinct? or why have those birds which arrive every year from the continent in the Atlantic islands introduced so few landshells? Hitherto the naturalist has not witnessed the arrival of a new continental Helix on any remote oceanic island, except by the aid of man; and to those who are unwilling to abandon in despair all hope of solving the problem, it is satisfactory that such should be the case. How inexplicable for example would be the dearth of land quadrupeds in the Atlantic islands if some members of this class were seen occasionally to swim across the ocean from Europe to the Azores!

If hereafter we should discover the mode in which air-breathing mollusks can sometimes traverse a wide expanse of ocean, we may be sure that the occasions of transport will be few and far between, so that a continental species when it colonises a new island has time to vary and to give rise to one or two new races, before other representatives of the original continental type follow in the same direction, so as to cross with the first settlers and check divergence.

If floating timber, or land-birds, or insects, or any other causes organic or inorganic, serve as the means of transport, their agency must be so casual and irregular as to cause the results to appear capricious in the extreme.

The first Miocene Helix which reached Madeira may have been of a different species from the first which reached Porto Santo. It has been imagined that *Helix inflexa* Martens, an extinct Miocene form of Europe, may have been the parent stock of *H. portosanctana*, of which the gigantic *H. Lowei* may be a variety, but the last-mentioned form seems never to have reached Madeira. The extinct *H. Raymondi*, so common in the French Faluns or Upper Miocene strata, is supposed

to have been the ancestral type of another common shell, *H. Bowditchiana* Pfeiffer, found both fossil and recent in Madeira and Porto Santo.

Let us assume that certain Miocene species, nearly all of them long since extinct, were carried as waifs and strays to separate islands by a concurrence of circumstances so rare as to happen once only in several hundred thousand years, other combinations of circumstances almost equally rare might be required to convey a species from one island to another. A volcanic eruption, for example, which might only occur once in the whole course of the building up of an archipelago, at exactly the same season of the year, or at the same height above the sea, with equal violence and when the wind or marine currents were in the same direction. Such a convulsion might cause the dispersion of some Helices from one part of an archipelago to another in a manner altogether without parallel during the antecedent or subsequent history of the same region. If the reader will refer to our description of the birth of Monte Nuovo, Vol. I. p. 608, near Naples, in 1538, he will see that while many land-birds were killed, those which escaped and flew terrified from the scene of the catastrophe, must, like the human inhabitants, have been covered with mud which was showered down so as to envelope all things. In the beginning of such an eruption trees, shrubs, and vegetable soil, in which the eggs of landshells must sometimes be included, would be hurled up into the air by the aqueous vapour. The eggs of a pupa are sometimes so minute and their terminal velocity in air so slight that they might be carried many miles by the wind before alighting on the ground—as far perhaps as from Madeira to the Dezertas. There is no reason for supposing that the tendency of species to form new varieties is greater in an oceanic island than on a continent. But if islands be separated from each other throughout so long a period as would be sufficient on the continent to change most of the species, then it is evident that there will be a greater manufacture of new species in the islands. Let us suppose a band of emigrants to have gone from some European country a thousand years ago and to have formed colonies in the

Canaries, and Madeiras, and that all communication between them and the mother country and between the different archipelagos was cut off for a thousand years, there would then be in all probability four languages spoken between the mother country and her three colonies all different from the original tongue of the ninth century. The population of the three archipelagos, like the area of land formed by the whole of them, might be very insignificant compared with that of the country from which the first emigrants proceeded, yet the smaller number of islanders, in consequence of their isolation, would have given rise to three new languages, and the inhabitants of the continent to one only. Not that the invention of new terms and idioms or the disuse of old ones would have gone on at a greater rate in the islands, but because each archipelago being separated from every other one and from the rest of the world, had formed an independent linguistic centre. In like manner the distinctness of the landshells in the Canaries, Madeiras, and Azores, and in many of the separate islands of each, are the results of the prolonged isolation of small fragments of land in mid-ocean, not of a greater tendency in the testacea inhabiting such islands to vary.

In conclusion I may observe, that the extent to which the species of mammalia, birds, insects, landshells, and plants, (whether flowering or cryptogamous,) agree with continental species, or the degree in which those of different archipelagos or of different islands of the same group agree with each other, has an unmistakeable relation to the known facilities enjoyed by each class of crossing the ocean. Such a relationship accords well with the theory of Variation and Natural Selection, but with no other hypothesis yet suggested for explaining the origin of species.

CHAPTER XLII.

EXTINCTION OF SPECIES.

CONDITIONS WHICH ENABLE EACH SPECIES OF PLANT TO MAINTAIN ITS GROUND AGAINST OTHERS—EQUILIBRIUM IN THE NUMBER OF SPECIES HOW PRESERVED—AGENCY OF INSECTS IN PRESERVING THIS EQUILIBRIUM—DEVASTATIONS CAUSED BY LOCUSTS—EFFECT OF OMNIVOROUS ANIMALS IN PRESERVING THE EQUILIBRIUM OF SPECIES—RECIPROCAL INFLUENCE OF AQUATIC AND TERRESTRIAL SPECIES—HOW CHANGES IN PHYSICAL GEOGRAPHY AFFECT THE DISTRIBUTION OF SPECIES—EXTENSION OF THE RANGE OF ONE SPECIES ALTERS THAT OF OTHERS—SUPPOSED EFFECTS OF THE FIRST ENTRANCE OF THE POLAR BEAR INTO ICELAND—INCREASE OF REIN-DEER IMPORTED INTO ICELAND—INFLUENCE OF MAN IN DERANGING THE NUMERICAL STRENGTH OF SPECIES—INDIGENOUS QUADRUPEDS AND BIRDS EXTIRPATED IN GREAT BRITAIN—EXTINCTION OF THE DODO—RAPID PROPAGATION OF DOMESTIC QUADRUPEDS OVER THE AMERICAN CONTINENT—POWER OF EXTERMINATING SPECIES NO PREROGATIVE OF MAN—CONCLUDING REMARKS ON EXTINCTION.

Conditions which enable each species of plant to maintain its ground against others.—I propose in this chapter to treat of the various causes to which the continual extinction of species, both in the animal and vegetable creation, is due.

Every naturalist is familiar with the fact, that although in a particular country, such as Great Britain, there may be more than 3,000 species of plants, 12,000 insects, and a great variety in each of the other classes; yet there will not be more than 100, perhaps not half that number, inhabiting any given locality. There may be no want of space in the supposed limited area: it may be a large mountain, or an extensive moor, or a great river-plain, containing room enough for individuals of every species in our island; yet the spot will be occupied by a few to the exclusion of many, and these few are enabled, throughout long periods, to maintain their ground successfully against every intruder, notwithstanding the facilities which species enjoy, by virtue of those powers of

diffusion already mentioned (Chapters XXXVIII., XXXIX., XL.), of invading adjacent territories.

The principal causes which enable a certain assemblage of plants thus to maintain their ground against all others depend, as is well known, on the relations between the physio logical nature of each species, and the climate, exposure, soil, and other physical conditions of the locality, and the power of each to compete with other organic beings in the struggle for life. Some plants live only on rocks, others in meadows, a third class in marshes. Of the latter, some delight in a fresh-water morass,—others in salt marshes, where their roots may copiously absorb saline particles. Some prefer an alpine region in a warm latitude, where, during the heat of summer, they are constantly irrigated by the cool waters of melting snows. To others loose sand, so fatal to the generality of species, affords the most proper station. The *Carex arenaria* and the *Elymus arenarius* acquire their full vigour on a sandy dune, obtaining an ascendancy over the very plants which in a stiff clay would immediately stifle them.

Where the soil of a district is of so peculiar a nature that it is extremely favourable to certain species, and agrees ill with every other, the former get exclusive possession of the ground, and as in the case of heaths, live in societies. In like manner the bog moss (*Sphagnum*) is fully developed in peaty swamps, and becomes, like the heath, in the language of botanists, a social plant. Such monopolies, however, are not common, for they are checked by various causes. Not only are many species endowed with equal powers to obtain and keep possession of similar stations, but the same spot of ground may for various reasons be more fit to support a new species than one which has long lived upon it. Oaks, for example, render the soil more fertile for the fir tribe, because the oak having spread its roots deeply and widely, leaves the soil near the surface in a practically virgin state, so that when by some cause, as a hurricane or a fire, the oak is destroyed, the young fir, whose small roots do not penetrate far below the surface, would, if its seeds were present and ready to germinate, find the soil fresh, and fitted for its nourishment.

So also any change of conditions, such as the submergence of a district, and its conversion into a marsh, or the destruction of an ancient forest by a hurricane, by causing heat, light, currents of air, moisture, or other influences to be felt for the first time in certain spots or districts, would naturally give an opportunity to new plants to establish themselves, and many generations might pass away before the original occupiers of the soil could again obtain possession of it.

Equilibrium in the number of species, how preserved.—'All the plants of a given country,' says De Candolle, in his usual spirited style, 'are at war with one another. The first which establish themselves by chance in a particular spot tend, by the mere occupancy of space, to exclude other species—the greater choke the smaller; the longest livers replace those which last for a shorter period; the more prolific gradually make themselves masters of the ground, which species multiplying more slowly would otherwise fill.'

In this continual strife, he observes, it is not always the resources of the plant itself which enable it to maintain or extend its ground. Its success depends, in a great measure, on the number of its foes or allies, among the animals and plants inhabiting the same region. Thus, for example, a herb which loves the shade may multiply, if some tree with spreading boughs and dense foliage flourish in the neighbourhood. Another, which, if unassisted, would be overpowered by the rank growth of some hardy competitor, is secure because its leaves are unpalatable to cattle; which, on the other hand, annually crop down its antagonist, and rarely suffer it to ripen its seed.

Oftentimes we see some herb which has flowered in the midst of a thorny shrub, when all the other individuals of the same species, in the open fields around, are eaten down, and cannot bring their seed to maturity. In this case, the shrub has lent his armour of spines and prickles to protect the defenceless herb against the mouths of the cattle; and thus a few individuals which occupied, perhaps, the most unfavourable station in regard to exposure, soil, and other circumstances, may, nevertheless, by the aid of an ally, become the principal source whereby the winds are supplied with

seeds which perpetuate the species throughout the surrounding tract.* Thus, in the New Forest in Hampshire, the young oaks which are not consumed by the deer, or uprooted by the swine, are often indebted to the holly for their escape.

In the above examples we see one plant shielding another from the attacks of animals; but instances are, perhaps, still more numerous, where some animal defends a plant against the enmity of some other subject of the vegetable kingdom. Scarcely any beast, observes Linnæus, will touch the nettle, but fifty different kinds of insects are fed by it.† Some of these seize upon the root, others upon the stem; some eat the leaves; others devour the seeds and flowers: but for this multitude of enemies, the nettle (*Urtica dioica*) would annihilate a great number of plants. The same naturalist tells us, in his 'Tour in Scania,' that goats were turned into an island which abounded with the *Agrostis arundinacea*, where they perished by famine; but horses which followed them grew fat on the same plant. The goat, also, he says, thrives on the meadow-sweet and water-hemlock, plants which are injurious to cattle.‡

Agency of insects.—Every plant, observes Wilcke, has its proper insect allotted to it to curb its luxuriancy, and to prevent it from multiplying to the exclusion of others. 'Thus grass in meadows sometimes flourishes so as to exclude all other plants: here the *Phalæna graminis* (*Bombyx gram.*), with her numerous progeny, finds a well-spread table; they multiply in immense numbers, and the farmer, for some years, laments the failure of his crop; but, the grass being consumed, the moths die with hunger, or remove to another place. Now the quantity of grass being greatly diminished, the other plants, which were before choked by it, spring up, and the ground becomes variegated with a multitude of different species of flowers. Had not Nature given a commission to this minister for that purpose the grass would destroy a great number of species of vegetables, of which the equilibrium is now kept up.' §

* Amœn. Acad. vol. vi. p. 17, § 12.

† Ibid.

‡ Ibid. vol. vii. p. 409.

§ Ibid. vol. vi. p. 17, § 11, 12.

In the above passage allusion is made to the ravages committed in 1740, and the two following years, in many provinces of Sweden, by a most destructive insect. The same moth is said never to touch the foxtail grass, so that it may be classed as a most active ally and benefactor of that species, and as peculiarly instrumental in preserving it in its present abundance.* A discovery of Rolander, cited in the treatise of Wilcke above mentioned, affords a good illustration of the checks and counter-checks which Nature has appointed to preserve the balance of power among species. 'The *Phalæna strobilella* has the fir-cone assigned to it to deposit its eggs upon; the young caterpillars coming out of the shell consume the cone and superfluous seed; but, lest the destruction should be too general, the *Ichneumon strobilellæ* lays its eggs in the caterpillar, inserting its long tail in the openings of the cone till it touches the included insect, for its body is too large to enter. Thus it fixes its minute egg upon the caterpillar, which being hatched, destroys it.' †

Entomologists enumerate many parallel cases where insects, appropriated to certain plants, are kept down by other insects, and these again by parasites expressly appointed to prey on them.‡ Few, perhaps, are in the habit of duly appreciating the extent to which insects are active in preserving the balance of species among plants, and thus regulating indirectly the relative numbers of many of the higher orders of terrestrial animals. The peculiarity of their agency consists in their power of suddenly multiplying their numbers to a degree which could only be accomplished in a considerable lapse of time in any of the larger animals, and then as instantaneously relapsing, without the intervention of any violent disturbing cause, into their former insignificance.

If, for the sake of employing, on different but rare occasions, a power of many hundred horses, we were under the necessity of feeding all these animals at great cost in the intervals when their services were not required, we should greatly admire the invention of a machine, such as the steam-engine, which was capable at any moment of exerting the same

* Kirby and Spence, vol. i. p. 178.

† Amœn. Acad. vol. vi. p. 26, § 14.

‡ Kirby and Spence, vol. iv. p. 218.

degree of strength without any consumption of food during periods of inaction. The same kind of admiration is strongly excited when we contemplate the powers of insect life, in the creation of which the Author of Nature has been so prodigal. A scanty number of minute individuals, to be detected only by careful research, are ready in a few days, weeks, or months, to give birth to myriads, which may repress any degree of monopoly in another species, or remove nuisances, such as dead carcasses, which might taint the air. But no sooner has the destroying commission been executed than the gigantic power becomes dormant—each of the mighty host soon reaches the term of its transient existence, and the season arrives when the whole species passes naturally into the egg, and thence into the larva and pupa state. In this defenceless condition it may be destroyed either by the elements, or by the augmentation of some of its numerous foes which may prey upon it in the early stages of its transformation; or it often happens that in the following year the season proves unfavourable to the hatching of the eggs or the development of the pupæ.

Thus the swarming myriads depart which may have covered the vegetation like the aphides, or darkened the air like locusts. In almost every season there are some species which in this manner put forth their strength, and then, like Milton's spirits, which thronged the spacious hall, 'reduce to smallest forms their shapes immense'—

> ———— So thick the aëry crowd
> Swarm'd and were straiten'd; till, the signal given,
> Behold a wonder! they but now who seemed
> In bigness to surpass earth's giant sons,
> Now less than smallest dwarfs.

A few examples will illustrate the mode in which this force operates. It is well known that, among the countless species of the insect creation, some feed on animal, others on vegetable matter; and, upon considering a catalogue of 8,000 British Insects and Arachnidæ, Mr. Kirby found that these two divisions were nearly a counterpoise to each other, the carnivorous being somewhat preponderant. There are also distinct species, some which consume living, others

dead or putrid animal and vegetable substances. One female, of *Musca carnaria*, will give birth to 20,000 young; and the larvæ of many flesh-flies devour so much food in twenty-four hours, and grow so quickly, as to increase their weight two hundred-fold! In five days after being hatched they arrive at their full growth and size, so that there was ground, says Kirby, for the assertion of Linnæus, that three flies of *M. vomitoria* could devour a dead horse as quickly as a lion;* and another Swedish naturalist remarks, that so great are the powers of propagation of a single species even of the smallest insects, that each can commit, when required, more ravages than the elephant.†

Next to locusts, the aphides, perhaps, exert the greatest power over the vegetable world, and, like them, are sometimes so numerous as to darken the air. The multiplication of these little creatures is without parallel, and almost every plant has its peculiar species. Reaumur has proved that in five generations one aphis may be the progenitor of 5,904,900,000 descendants; and it is supposed that in one year there may be twenty generations.‡ Mr. Curtis observes that, as among caterpillars we find some that are constantly and unalterably attached to one or more particular species of plants, and others that feed indiscriminately on most sorts of herbage, so it is precisely with the aphides: some are particular, others more general feeders; and as they resemble other insects in this respect, so they do also in being more abundant in some years than in others.§ In 1793 they were the chief, and in 1798 the sole, cause of the failure of the hops. In 1794, a season almost unparalleled for drought, the hop was perfectly free from them; while peas and beans, especially the former, suffered very much from their depredations.

The ravages of the caterpillars of some of our smaller moths afford a good illustration of the temporary increase of a species. The oak trees of a considerable wood have been stripped of their leaves as bare as in winter, by the caterpillars of a small green moth (*Tortrix viridana*), which has been observed the year following not to abound. The silver Y moth

* Kirby and Spence, vol. i. p. 250.
† Wilcke, Amœn. Acad. c. ii.
‡ Kirby and Spence, vol. i. p. 174.
§ Trans. Linn. Soc. vol. vi.

(*Plusia gamma*), although one of our common species, is not dreaded by us for its devastations; but legions of their caterpillars have at times created alarm in France, as in 1735. Reaumur observes that the female moth lays about 400 eggs; so that if twenty caterpillars were distributed in a garden, and all lived through the winter and became moths in the succeeding May, the eggs laid by these, if half of them were female and all fertile, would in the next generation produce 800,000 caterpillars.* A modern writer, therefore, justly observes that, did not Providence put causes in operation to keep them in due bounds, the caterpillars of this moth alone, leaving out of consideration the 2,000 other British species, might soon destroy more than half of our vegetation.

In the latter part of the last century an ant most destructive to the sugar-cane (*Formica saccharivora*), appeared in such infinite hosts in the island of Grenada, as to put a stop to the cultivation of that vegetable. Their numbers were incredible. The plantations and roads were filled with them; many domestic quadrupeds, together with rats, mice, and reptiles, and even birds, perished in consequence of this plague. It was not till 1780 that they were at length annihilated by torrents of rain, which accompanied a dreadful hurricane.†

Devastations caused by locusts. — We may conclude by mentioning some instances of the devastations of locusts in various countries. Among other parts of Africa, Cyrenaica has been at different periods infested by myriads of these creatures which have consumed nearly every green thing. The effect of the havoc committed by them may be estimated by the famine they occasioned. St. Augustine mentions a plague of this kind in Africa which destroyed no less than 800,000 men in the kingdom of Massinissa alone, and many more upon the territories bordering upon the sea. It is also related, that in the year 591, an infinite army of locusts migrated from Africa into Italy; and, after grievously ravaging the country, were cast into the sea, when there arose a pestilence from their stench which carried off nearly a million of men and beasts.

* Reaumur, vol. ii. p. 337.

† Kirby and Spence, vol. i. p. 183. Castle, Phil. Trans., xxx. 346.

In the Venetian territory, also, in 1478, more than 30,000 persons are said to have perished in a famine occasioned by this scourge; and other instances are recorded of their devastations in France, Spain, Italy, Germany, &c. In different parts of Russia also, Hungary, and Poland, in Arabia and India, and other countries, their visitations have been periodically experienced. Although they have a preference for certain plants, yet, when these are consumed, they will attack almost all the remainder. In the accounts of the invasions of locusts, the statements which appear most marvellous relate to the prodigious mass of matter which encumbers the sea wherever they are blown into it, and the pestilence arising from its putrefaction. Their dead bodies are said to have been, in some places, heaped one upon another, to the depth of four feet, in Russia, Poland, and Lithuania; and when, in Southern Africa, they were driven into the sea, by a north-west wind, they formed, says Barrow along the shore, for fifty miles, a bank three or four feet high.* But when we consider that forests are stripped of their foliage, and the earth of its green garment, for thousands of square miles, it may well be supposed that the volume of animal matter produced may equal that of great herds of quadrupeds and flights of large birds suddenly precipitated into the sea.

The occurrence of such events at certain intervals, in hot countries, like the severe winters and damp summers returning after a series of years in the temperate zone, may affect the proportional numbers of almost all classes of animals and plants, and probably prove fatal to the existence of many which would otherwise thrive there; while, on the contrary, the same occurrences can scarcely fail to be favourable to certain species which, if deprived of such aid, might not maintain their ground.

Although it may usually be remarked that the extraordinary increase of some one species is immediately followed and checked by the multiplication of another, yet this does not always happen; partly because many species feed in common on the same kinds of food, and partly because many kinds of

* Travels in Africa, p. 257. Kirby and Spence, vol. i. p. 215.

food are often consumed indifferently by one and the same species. In the former case, where a variety of different animals have precisely the same taste, as, for example, when many insectivorous birds and reptiles devour alike some particular fly or beetle, the unusual numbers of these insects may cause only a slight and almost imperceptible augmentation of each of these species of bird and reptile. In the other instance, where one animal preys on others of almost every class, as, for example, where some of our English hawks or buzzards (*Buteo*) devour not only small quadrupeds, as rabbits and field-mice, but also birds, frogs, lizards, and insects, the profusion of any one of these last may cause all such general feeders to subsist more exclusively upon the species thus in excess, by which means the balance may be restored.

Agency of omnivorous animals.—The number of species which are nearly omnivorous is considerable; and although every animal has, perhaps, a predilection for some one description of food rather than another, yet some are not even confined to one of the great kingdoms of the organic world. Thus, when the racoon of the West Indies can procure neither fowls, fish, snails, nor insects, it will attack the sugar canes, and devour various kinds of grain. The civets, when animal food is scarce, maintain themselves on fruits and roots. Numerous birds, which feed indiscriminately on insects and plants, are perhaps more instrumental than any other of the terrestrial tribes in preserving a constant equilibrium between the relative numbers of different classes of animals and vegetables. If the insects become very numerous and devour the plants, these birds will immediately derive a larger portion of their subsistence from insects, just as the Arabians, Syrians, and Hottentots feed on locusts, when the locusts devour their crops.

Reciprocal influence of aquatic and terrestrial species.—The intimate relation of the inhabitants of the water to those of the land, and the influence exerted by each on the relative number of species, must not be overlooked amongst the complicated causes which determine the existence of animals and plants in certain regions. A large portion of the amphibious

quadrupeds and reptiles prey partly on aquatic plants and animals, and in part on terrestrial; and a deficiency of one kind of prey causes them to have immediate recourse to the other. The voracity of certain insects, as the dragon-fly, for example, is confined to the water during one stage of their transformations, and in their perfect state to the air. Innumerable water-birds, both of rivers and seas, derive in like manner their food indifferently from either element; so that the abundance or scarcity of prey in one induces them either to forsake or more constantly to haunt the other. Thus an intimate connection between the state of the animate creation in a lake or river, and in the adjoining dry land, is maintained; or between a continent, with its lakes and rivers, and the ocean. It is well known that many birds migrate, during stormy seasons, from the sea-shore into the interior, in search of food; while others, on the contrary, urged by like wants, forsake their inland haunts, and live on substances rejected by the tide.

The migration of fish into rivers during the spawning season supplies another link of the same kind. Suppose the salmon to be reduced in numbers by some marine foes, as by seals and grampuses, the consequence must often be, that in the course of a few years the otters at the distance of several hundred miles inland, will be lessened in number from the scarcity of fish. On the other hand, if there be a dearth of food for the young fry of the salmon in rivers and estuaries, so that few return to the sea, the sand-eels and other marine species, which are usually kept down by the salmon, will swarm in greater profusion.

It is unnecessary to accumulate more illustrations in order to prove that the stations of different plants and animals depend on a great complication of circumstances,—on an immense variety of relations in the state of the animate and inanimate worlds. Every plant requires a certain climate, soil, and other conditions, and often the aid of many animals, in order to maintain its ground. Many animals feed on certain plants, being often restricted to a small number, and sometimes to one only; other members of the animal kingdom feed on plant-eating species, and thus become dependent on

the conditions of the *stations* not only of their prey, but of the plants consumed by them.

How changes in physical geography affect the distribution of species.—Thus by means of numerous checks and counter-checks the state of the animal and vegetable kingdoms continues from century to century, and even perhaps for tens of thousands of years, the same, except where man interferes; but independently of human intervention, neither the zoological nor botanical provinces can remain for indefinite periods unaltered.

Nature is continually engaged in the task of sowing seeds and colonising animals; were this not the case the depopulation of a certain portion of the habitable sea and land would, even in a few years, be considerable, so great is the instability of the earth's surface. Whenever a river transports sediment into a lake or sea, so as materially to diminish its depth, the aquatic animals and plants which delight in deep water are expelled: the tract, however, is not allowed to remain useless; but is soon peopled by species which require more light and heat, and thrive where the water is shallow. Every addition made to the land by the encroachment of the delta of a river banishes many aquatic species from their native abodes; but the new-formed plain is not permitted to lie unoccupied, being instantly covered with terrestrial vegetation. The ocean devours continuous lines of sea-coasts, and precipitates forests or rich pasture land into the waves; but this space is not lost to the animate creation; for shells and sea-weeds soon adhere to the new-made cliffs, and numerous fish people the channel which the current has scooped out for itself. No sooner has a volcanic island been thrown up than some lichens begin to grow upon it, and it is sometimes clothed with verdure while smoke and ashes are still occasionally thrown from the crater. The cocoa, pandanus, and mangrove take root upon the coral reef before it has fairly risen above the waves. The burning stream of lava that descends from Etna rolls through the stately forest, and converts to ashes every tree and herb which stands in its way; but the black strip of land thus desolated is covered again, in the course of time, with oaks,

pines, and chestnuts, as luxuriant as those which the fiery torrent swept away.

Every flood and landslip, every wave which a hurricane or earthquake throws upon the shore, every stream of lava or shower of volcanic dust and ashes which buries a country far and wide to the depth of many feet, every advance of the sand-flood, every conversion of salt water into fresh, when rivers alter their main channel of discharge, every permanent variation in the rise or fall of tides in an estuary—these and countless other causes displace, in the course of a few centuries, certain plants and animals from stations which they previously occupied. If, therefore, the Author of Nature had not been prodigal of those numerous contrivances, before alluded to, for spreading all classes of organic beings over the earth—if He had not ordained that the fluctuations of the animate and inanimate creation should be in perfect harmony with each other, it is evident that considerable spaces, now the most habitable on the globe, would soon be as devoid of life as are the Alpine snows, or the moving sands and salt plains of the Sahara.

The powers, then, of migration and diffusion, conferred, as already shown, on animals and plants, are indispensable to enable them to maintain their ground, and would be necessary, even though it were never intended that a species should gradually extend its geographical range. But a facility of shifting their quarters being once given, it cannot fail to happen that the inhabitants of one province should occasionally penetrate into some other; since the strongest of those barriers which I before described as separating distinct regions are all liable to be thrown down, one after the other, during the vicissitudes of the earth's surface.

We have seen in the Twelfth Chapter* how vast a succession of changes in the physical geography of the globe has been revealed to us by geology. Although these changes are incessant, they proceed at so slow a rate that mankind at large are wholly unconscious of their reality. It would not be easy for the naturalist to take account of the advantage which one

* Vol. I. p. 252.

species may gain over another in the course of a few centuries, even at those points on the borders of two distinct provinces where the struggle for existence is most keen. At such points the rate of change must far outstrip the average pace at which it proceeds in the organic world generally. If the ocean should gradually wear its way through an isthmus, like that of Suez, it would open a passage for the intermixture of the aquatic tribes of two seas (the Mediterranean and Red Sea) previously disjoined, and would, at the same time, close a free communication which the terrestrial plants and animals of two continents had before enjoyed. These would be, perhaps, the most important consequences, in regard to the distribution of species, which would result from the breach made by the sea in such a spot; but there would be others of a distinct nature, such as the conversion of a certain tract of land, which formed the isthmus, into the sea. This space, previously occupied by terrestrial plants and animals, would be immediately delivered over to the aquatic; a local revolution which might have happened in innumerable other parts of the globe, without being attended by any alteration in the blending together of the species of two distinct provinces.

So if the narrow isthmus of Panama were to sink down gradually, a communication would at length be established between two seas which are now inhabited by fish, mollusks, crustaceans, and other aquatic tribes nearly all of them specifically distinct. A contest would take place between thousands of allied species which in the course of time would give rise to the predominance of some and the decline or total extinction of others. If Spain were joined to Morocco, by the upheaval and laying dry of the submarine ridge 1,000 feet deep, before described,* the Mediterranean fauna would be separated from that of the Atlantic, and there would be a fusion of the terrestrial plants of Northern Africa with those of Southern Europe. Or we may imagine a land communication to be caused by volcanic outbursts in the straits of Lombok,† uniting the islands of Bali and Lombok. This would bring

* See above, Vol. I. p. 496. † See Map, fig. 138, p. 350.

about a conflict between the land-birds, insects, and plants of the Indian and Australian provinces, which could not fail to add to the numerical predominance of some species at the expense of others, while some might be exterminated. But even such fluctuations would to a human observer appear slow in the extreme, because a communication formed by a new volcanic island will not simply take thousands of years, but perhaps thousands of centuries, for its accomplishment, and few of the species capable of profiting by the removal of the old barrier would wait till the two islands were completely joined.

Extension of the range of one species alters that of others.—In reference to the extinction of species it is important to bear in mind, that when any region is stocked with as great a variety of animals and plants as its productive powers will enable it to support, the addition of any new species to the *permanent* numerical increase of one previously established, must always be attended either by the local extermination or the numerical decrease of some other species.

There may undoubtedly be considerable fluctuations from year to year, and the equilibrium may be again restored without any permanent alteration; for, in particular seasons, a greater supply of heat, humidity, or other causes, may augment the total quantity of vegetable produce, in which case all the animals subsisting on vegetable food, and others which prey on them, may multiply without any one species giving way: but whilst the aggregate quantity of vegetable produce remains unaltered, the progressive increase of one animal or plant implies the decline of another.

All agriculturists and gardeners are familiar with the fact that when weeds intrude themselves into the space appropriated to cultivated species, the latter are starved in their growth or stifled. If we abandon for a short time a field or garden, a host of indigenous plants,

The darnel, hemlock, and rank fumitory,

pour in and obtain the mastery, extirpating the exotics, or putting an end to the monopoly of some native plants.

If we enclose a park, and stock it with as many deer as the

herbage will support, we cannot add sheep without lessening the number of the deer; nor can other herbivorous species be subsequently introduced, unless the individuals of each species in the park become fewer in proportion.

So, if there be an island where leopards are the only beasts of prey, and the lion, tiger, and hyæna afterwards enter, the leopards, if they stand their ground, will be reduced in number. If the locusts then arrive and swarm greatly, they may deprive a large number of plant-eating animals of their food, and thereby cause a famine, not only among them, but among the beasts of prey: certain species, perhaps, which had the weakest footing in the island may thus be annihilated. Although our knowledge of the history of the animate creation dates from so recent a period, that we can scarcely trace the advance or decline of any animal or plant, except in those cases where the influence of man has intervened; yet we can easily conceive what must happen when some new colony of wild animals or plants enters a region for the first time, and succeeds in establishing itself.

Supposed effects of the first entrance of the polar bear into Iceland.—Let us consider how great are the devastations committed at certain periods by the Greenland bears, when they are drifted to the shores of Iceland in considerable numbers on the ice. These periodical invasions are formidable even to man; so that when the bears arrive, the inhabitants collect together, and go in pursuit of them with fire-arms—each native who slays one being rewarded by the king of Denmark. The Danes of old, when they landed in their marauding expeditions upon our coast, hardly excited more alarm, nor did our islanders muster more promptly for the defence of their lives and property against the common enemy, than the modern Icelanders against these formidable brutes. It often happens, says Henderson, that the natives are pursued by the bear when he has been long at sea, and when his natural ferocity has been heightened by the keenness of hunger; if unarmed, it is frequently by stratagem only that they make their escape.*

* Journal of a Residence in Iceland, p. 27.

Let us cast our thoughts back to the period when the first polar bears reached Iceland, before it was colonised by the Norwegians in 874; we may imagine the breaking up of an immense barrier of ice like that which, in 1816 and the following year, disappeared from the east coast of Greenland, which it had surrounded for four centuries. By the aid of such means of transportation a great number of these quadrupeds might effect a landing at the same time, and the havoc which they would make among the species previously settled in the island would be terrific. The deer, foxes, seals, and even birds, on which these animals sometimes prey, would be soon thinned down.

But this would be a part only, and probably an insignificant portion, of the aggregate amount of change brought about by the new invader. The plants on which the deer fed, being less consumed in consequence of the lessened numbers of that herbivorous species, would soon supply more food to several insects, and probably to some terrestrial testacea, so that the latter would gain ground. The increase of these would furnish other insects and birds with food, so that the numbers of these last would be augmented. The diminution of the seals would afford a respite to some fish which they had persecuted; and these fish, in their turn, would then multiply and press upon their peculiar prey. Many water-fowls, the eggs and young of which are devoured by foxes, would increase when the foxes were thinned down by the bears; and the fish on which the water-fowls subsisted would then, in their turn, be less numerous. Thus the numerical proportions of a great number of the inhabitants, both of the land and sea, might be permanently altered by the settling of one new species in the region; and the changes caused indirectly would ramify through all classes of the living creation, and be almost endless.

An actual illustration of what we have here only proposed hypothetically, is in some degree afforded by the selection of small islands by the eider duck for its residence during the season of incubation, its nests being seldom if ever found on the shores of the mainland, or even of a large island. The Icelanders are so well aware of this, that they have expended

a great deal of labour in forming artificial islands, by separating from the main land certain promontories, joined to it by narrow isthmuses. This insular position is necessary to guard against the destruction of the eggs and young birds, by foxes, dogs, and other animals. One year, says Sir W. Hooker, it happened that, in the small island of Vidoe, adjoining the coast of Iceland, a fox got over *upon the ice*, and caused great alarm, as an immense number of ducks were then sitting on their eggs or young ones. It was long before he was taken, which was at last, however, effected by bringing another fox to the island, and fastening it by a string near the haunt of the former, by which he was allured within shot of the hunter.*

Increase of reindeer imported into Iceland.—As an example of the rapidity with which a large tract may become peopled by the offspring of a single pair of quadrupeds, it may be mentioned that in the year 1773 thirteen reindeer were exported from Norway, only three of which reached Iceland. These were turned loose into the mountains of Guldbringè Syssel, where they multiplied so greatly, in the course of forty years, that it was not uncommon to meet with herds, consisting of from forty to one hundred, in various districts.

The reindeer, observes a modern writer, is in Lapland a loser by his connection with man, but Iceland will be this creature's paradise. There is, in the interior, a tract which Sir G. Mackenzie computes at not less than 40,000 square miles, without a single human habitation, and almost entirely unknown to the natives themselves. There are no wolves; the Icelanders will keep out the bears; and the reindeer, being almost unmolested by man, will have no enemy whatever, unless it has brought with it its own tormenting gad-fly.†

Ulloa in his voyage, and Buffon on the authority of old writers, relate a fact which illustrates very clearly the principle before explained, of the check which the increase of one animal necessarily offers to that of another. The Spaniards

* Tour in Iceland, vol. i. p. 64, 2nd edit. † Travels in Iceland in 1810, p. 342

had introduced goats into the island of Juan Fernandez, where they became so prolific as to furnish the pirates, who infested those seas, with provisions. In order to cut off this resource from the buccaneers, a number of dogs were turned loose into the island; and so numerous did they become in their turn, that they destroyed the goats in every accessible part, after which the number of the wild dogs again decreased.*

It is usually the first appearance of an animal or plant, in a region to which it was previously a stranger, that gives rise to the chief alteration; since, after a time, an equilibrium is again established. But it must require ages before such a new adjustment of the relative forces of so many conflicting agents can be definitely settled. The causes in simultaneous action are so numerous, that they admit of an almost infinite number of combinations; and it is necessary that all these should have occurred once before the total amount of change, capable of flowing from any new disturbing force, can be estimated.

Thus, for example, suppose that once in two centuries a frost of unusual intensity, or a volcanic eruption of great violence accompanied by floods from the melting of glaciers, should occur in Iceland; or an epidemic disease, fatal to the larger number of individuals of some one species, and not affecting others,—these, and a variety of other contingencies, all of which may occur at once, or at periods separated by different intervals of time, ought to happen before it would be possible for us to declare what ultimate alteration the presence of any new comers, such as the bear or reindeer before mentioned, might occasion in the animal population of the isle.

Every new condition in the state of the organic or inorganic creation, a new animal or plant, an additional snow-clad mountain, any permanent change, however slight in comparison to the whole, gives rise to a new order of things, and may make a material change in regard to some one or more species. Yet a swarm of locusts, or a frost of extreme intensity, or an epidemic disease, may pass away without any

* Buffon, vol. v. p. 100. Ulloa's Voyage, vol. ii. p. 220.

great apparent derangement; no species may be lost, and all may soon recover their former relative numbers, because the same scourges may have visited the region again and again, at preceding periods. Every plant that was incapable of resisting such a degree of cold, every animal which was exposed to be entirely cut off by an epidemic or by famine caused by the consumption of vegetation by the locusts, may have perished already, so that the subsequent recurrence of similar catastrophes is attended only by a temporary change.

Extirpation of species by man.—That man is, geologically speaking, of very modern origin we may assume, although we have recently obtained satisfactory proofs that he was contemporary with the mammoth and many other extinct mammalia, and that he has survived considerable changes in the physical geography of the globe.

The number of human beings now peopling the earth is generally supposed to amount to eight hundred millions, so that we may easily understand how great a number of beasts of prey, birds, and animals of every class, this prodigious population must have displaced, independently of the still more important consequences which have followed from the derangement brought about by man in the relative numerical strength of particular species.

It may perhaps be said, that man has, in no small degree, compensated for the appropriation to himself of the food of many animals by artificially improving the natural productiveness of soils, by irrigation, manure, and a judicious intermixture of mineral ingredients conveyed from different localities. But it admits of reasonable doubt whether, upon the whole, we fertilise or impoverish the lands which we occupy. This assertion may seem startling to many; because they are so much in the habit of regarding the sterility or productiveness of land in relation to the wants of man, and not as regards the organic world generally. It is difficult, at first, to conceive, if a morass be converted into arable land, and made to yield a crop of grain, even of moderate abundance, that we have not improved the capabilities of the habitable surface—that we have not empowered it to support

a larger quantity of organic life. In such cases, however, a tract, before of no utility to man, may be reclaimed, and become of high agricultural importance, though it may, nevertheless, yield a scantier vegetation. If a lake be drained, and turned into a meadow, the space will provide sustenance for man, and many terrestrial animals serviceable to him, but not, perhaps, so much food as it previously yielded to the aquatic races.

The felling of dense and lofty forests, which covered, even within the records of history, a considerable space on the globe, now tenanted by civilised man, must generally have lessened the amount of vegetable food throughout the space where these woods grew. We must also take into our account the area covered by towns, and a still larger surface occupied by roads.

If we force the soil to bear extraordinary crops one year, we are, perhaps, compelled to let it lie fallow the next. But nothing so much counterbalances the fertilising effects of human art as the extensive cultivation of foreign herbs and shrubs, which, although they are often more nutritious to man, seldom thrive with the same rank luxuriance as the native plants of a district. Man is, in truth, continually striving to diminish the natural diversity of the *stations* of animals and plants in every country, and to reduce them all to a small number fitted for species of economical use. He may succeed perfectly in attaining his object, even though the vegetation be comparatively meagre, and the total amount of animal life be greatly lessened.

When St. Helena was discovered about the year 1506, it was entirely covered with forests, the trees drooping over the tremendous precipices that overhang the sea. Now, says Dr. Hooker, all is changed; fully five-sixths of the island are entirely barren, and by far the greater part of the vegetation which exists, whether herbs, shrubs, or trees, consists of introduced European, American, African, and Australian plants, which propagated themselves with such rapidity that the native plants could not compete with them. These exotic species, together with the goats, which being carried to the island destroyed the forests by devouring all

the young plants, are supposed to have utterly annihilated about 100 peculiar and indigenous species, all record of which is lost to science, except those of which specimens were collected by the late Dr. Burchell and are now in the herbarium of Kew.*

In the district of Canterbury, New Zealand, Mr. Locke Travers, writing in 1863, says that the spread of European and other foreign plants is surprisingly rapid. The cow-grass (*Polygonum aviculare*), the common dock, and the sow thistle grow luxuriantly, the water-cress increases in the still rivers so as to threaten to choke them up altogether, and to put the colonists to the expense of £300 annually in keeping open a single stream, the Avon, which runs through Christchurch. Stems of this water-cress have been measured 12 feet long and three quarters of an inch in diameter. In some mountain districts the white clover is displacing the native grasses, and foreign trees, such as poplars, and willows, and the gum-trees of Australia, are growing rapidly. In fact, the young native vegetation appears to shrink from competition with these more vigorous intruders.'†

Spix and Martius have given a lively description of the incredible number of insects which lay waste the crops in Brazil, besides swarms of monkeys, flocks of parrots, and other birds, as well as the paca, agouti, and wild swine. They describe the torment which the planter and the naturalist suffer from the musquitoes, and the devastation of the ants and blattæ; they speak of the dangers to which they were exposed from the jaguar, the poisonous serpents, crocodiles, scorpions, centipedes, and spiders. But with the increasing population and cultivation of the country, say these naturalists, these evils will gradually diminish; when the inhabitants have cut down the woods, drained the marshes, made roads in all directions, and founded villages and towns, man will, by degrees, triumph over the rank vegetation and the noxious animals, and all the elements will second and amply recompense his activity.‡

* Hooker, Insular Floras, Brit. Assoc. Nottingham, 1866. Gardener's Chronicle, 1867.

† Locke Travers, cited by Hooker, Nat. Hist. Rev. 1864, p. 124.

‡ Travels in Brazil, vol. i. p. 260.

Indigenous quadrupeds and birds extirpated in Great Britain. —Let us make some enquiries into the extent of the influence which the progress of society has exerted during the last seven or eight centuries, in altering the distribution of indigenous British animals. Dr. Fleming, in an able memoir on the subject, has enumerated the best authenticated examples of the decrease or extirpation of certain species during a period when our population has made the most rapid advances. I shall offer a brief outline of his results.*

The stag, as well as the fallow deer and the roe, were formerly so abundant in our island, that, according to Lesley, from five hundred to a thousand were slain at a hunting-match; but the native races would already have been extinguished, had they not been carefully preserved in certain forests. The otter, the marten, and the polecat were also in sufficient numbers to be pursued for the sake of their fur; but they have now been reduced within very narrow bounds. The wild cat and fox have also been sacrificed throughout the greater part of the country, for the security of the poultry-yard or the fold. Badgers have been expelled from nearly every district, which at former periods they inhabited.

Besides these, which have been driven out from their favourite haunts, and everywhere reduced in number, there are some which have been wholly extirpated; such as the ancient breed of indigenous horses, and the wild boar; of the wild oxen a few remains are still preserved in some of the old English parks. The beaver, which is eagerly sought after for its fur, had become scarce at the close of the ninth century; and, by the twelfth century, was only to be met with, according to Giraldus de Barri, in one river in Wales, and another in Scotland. The wolf, once so much dreaded by our ancestors, is said to have maintained its ground in Ireland so late as the beginning of the eighteenth century (1710), though it had been extirpated in Scotland thirty years before, and in England at a much earlier period. The bear, which, in Wales, was regarded as a beast of chase equal to

* Ed. Phil. Journ., No. xxii. p. 287. Oct. 1824.

the hare or the boar, only perished, as a native of Scotland, in the year 1057.*

Many native birds of prey have also been the subjects of unremitting persecution. The eagles, larger hawks, and ravens, have disappeared from the more cultivated districts. The haunts of the mallard, the snipe, the redshank, and the bittern, have been drained equally with the summer dwellings of the lapwing and the curlew. But these species still linger in some portion of the British Isles; whereas the larger capercailzies, formerly natives of the pine-forests of Ireland and Scotland, had been quite destroyed towards the close of the last century, but were successfully reintroduced into Perthshire about the year 1824. The egret and the crane, which appear to have been formerly very common in Scotland, are now only occasional visitants.†

The bustard (*Otis tarda*), observes Graves, in his British Ornithology,‡ 'was formerly seen on the downs and heaths of various parts of our island, in flocks of forty or fifty birds; whereas it is now (1821) a circumstance of rare occurrence to meet with a single individual.' Bewick also remarks, 'that they were formerly more common in this island than at present; they are now found only in the open counties of the south and east—in the plains of Wiltshire, Dorsetshire, and some parts of Yorkshire.'§ In the few years that have elapsed since Bewick wrote, this bird has entirely disappeared from the British Isles. These changes, it may be observed, are derived from very imperfect memorials, and relate only to the larger and more conspicuous animals inhabiting a small spot on the globe; but they cannot fail to exalt our conception of the enormous revolutions which, in the course of thousands of years, the whole human species must have effected.

Extinction of the dodo.—The kangaroo and the emu are retreating rapidly before the progress of colonisation in Australia; and it scarcely admits of doubt, that the general cultivation of that country must lead to the extirpation of both. The most striking example of the loss, even within the last

* Fleming, Ed. Phil. Journ. No. xxii. p. 295.

† Fleming, ibid., p. 292.

‡ Vol. iii. London, 1821.

§ Land Birds, vol. i., p. 316, ed. 1821.

two centuries, of a remarkable species, is that of the dodo—a bird first seen by the Dutch, when they landed on the Isle of France, at that time uninhabited, immediately after the discovery of the passage to the East Indies by the Cape of Good Hope. It was of a large size, and singular form; its wings short, like those of an ostrich, and wholly incapable of sustaining its heavy body, even for a short flight. In its general appearance it differed from the ostrich, cassowary, or any known bird.*

Many naturalists gave figures of the dodo after the commencement of the seventeenth century; and there is a painting of it in the British Museum, which is said to have been taken from a living individual. Beneath the painting is a leg, in a fine state of preservation, which ornithologists are agreed cannot belong to any other known bird. In the museum at Oxford, also, there is a foot and a head in an imperfect state.

In spite of the most active search, during the last century, no information respecting the dodo was obtained, and some authors went so far as to pretend that it had never existed; but a great mass of satisfactory evidence in favour of its recent existence has now been collected by Mr. Broderip,† and by Mr. Strickland and Dr. Melville. Mr. Strickland, agreeing with Professor Reinhardt, of Copenhagen, in referring the dodo to the Columbidæ, called it a 'vulture-like frugivorous pigeon.' It appears, also, that another short-winged bird of the same order, called 'The Solitaire,' inhabited the island of Rodrigues, 300 miles east of the Mauritius, and has been exterminated by man, as have one or two different but allied birds of the Isle of Bourbon.‡ In

* Some have complained that inscriptions on tomb-stones convey no general information, except that individuals were born and died, accidents which must happen alike to all men. But the death of a *species* is so remarkable an event in natural history that it deserves commemoration, and it is with no small interest that we learn, from the archives of the University of Oxford, the exact day and year when the remains of the last specimen of the dodo, which had been permitted to rot in the Ashmolean Museum, were cast away. The relics, we are told, were 'a musæo subducta, annuente vice-cancellario aliisque curatoribus, ad ea lustranda convocatis, die Januarii 8vo, A.D. 1755.' Zool. Journ. No. 12, p. 559. 1828.

† Penny Cyclopædia, 'Dodo,' 1837.

‡ Messrs. Strickland and Melville on 'the Dodo and its Kindred.' London, 1848.

the year 1865 parts of the skeleton of a dodo were dug up in a bog near the sea in the island of Mauritius. They were sent to Professor Owen, and were described by him in the Transactions of the Zoological Society for 1867.* Speaking of the extinct bird as the great 'ground-dove' of the Mauritius, he speculates on this peculiar species having originated in that uninhabited and thickly wooded island, where there was no animal powerful enough to contend with it and from which it would be required to escape by flight. He therefore conceives that 'finding food enough scattered over the ground, it ceased to exert its wings in raising the heavy trunk, and so gradually gained bulk in the course of many generations. Hence the organs of flight would, according to Lamarckian principles, be atrophied by disease and diminished in size and strength, while the hind limbs, having an increasing weight to support and being exercised by habitual motion on the land, would acquire larger dimensions.' †

Rapid propagation of domestic quadrupeds over the American continent.—The agency of man in multiplying the numbers of large herbivorous quadrupeds of domesticated races may be regarded as one of the most obvious causes of the extermination of species. On this, and on several other grounds, the introduction of the horse, ox, and other mammalia, into America, and their rapid propagation over that continent within the last three centuries, is a fact of great importance in natural history. The extraordinary herds of wild cattle and horses which overran the plains of South America sprang from a very few pairs first carried over by the Spaniards; and they prove that the wide geographical range of large species in great continents does not necessarily imply that they have existed there from remote periods.

Humboldt observes, in his Travels, on the authority of Azara, that it is believed that there exist, in the Pampas of Buenos Ayres, twelve million cows and three million horses,

* Since this date more remains have been discovered, from which an almost perfect skeleton has been constructed at the British Museum, descriptions and figures of which were published by Prof. Owen in 1871. Trans. of the Zool. Soc. vol. vii. p. 513.

† Zool. Soc. Trans. 1867.

without comprising in this enumeration the cattle that have no acknowledged proprietor. In the Llanos of Caraccas, the rich hateros, or proprietors of pastoral farms, are entirely ignorant of the number of cattle they possess. The young are branded with a mark peculiar to each herd, and some of the most wealthy owners mark as many as 14,000 a year.* In the northern plains, from the Orinoco to the lake of Maracaybo, M. Depons reckoned that 1,200,000 oxen, 180,000 horses, and 90,000 mules, wandered at large.† In some parts of the valley of the Mississippi, especially in the country of the Osage Indians, wild horses were immensely numerous in the early part of this century.

The establishment of black cattle in America dates from Columbus's second voyage to St. Domingo. They there multiplied rapidly; and that island presently became a kind of nursery from which these animals were successively transported to various parts of the continental coast, and from thence into the interior. Notwithstanding these numerous exportations, in twenty-seven years after the discovery of the island, herds of 4,000 head, as we learn from Oviedo, were not uncommon, and there were even some that amounted to 8,000. In 1587, the number of hides exported from St. Domingo alone, according to Acosta's report, was 35,444; and in the same year there were exported 64,350, from the ports of New Spain. This was in the sixty-fifth year after the taking of Mexico, previous to which event the Spaniards, who came into that country, had not been able to engage in anything else than war.‡ Everyone is aware that these animals are now established throughout the American continent from Canada to the Straits of Magellan.

The ass has thriven very generally in the New World; and we learn from Ulloa, that in Quito they ran wild, and multiplied in amazing numbers, so as to become a nuisance. They grazed together in herds, and when attacked defended themselves with their mouths. If a horse happened to stray into the places where they fed, they all fell upon him, and did not cease biting and kicking till they left him dead.§ This fact

* Pers. Nar. vol. iv.

† Quarterly Review, vol. xxi. p. 335.

‡ Ibid.

§ Ulloa's Voyage. Wood's Zoog. vol. i. p. 9.

illustrates the power of one of those barriers—namely, that of preoccupancy, which we before alluded to (p. 133)—as being often most effective in limiting the range of species.

The first hogs were carried to America by Columbus, and established in the island of St. Domingo the year following its discovery, in November, 1493. In succeeding years they were introduced into other places where the Spaniards settled, and, in the space of half a century, they were found established in the New World, from the latitude of 25° north, to the 40th degree of south latitude. Sheep, also, and goats have multiplied enormously in the New World, as have also the cat and the rat, which last, as before stated, has been imported unintentionally in ships. The dogs introduced by man which have at different periods become wild in America, hunted in packs, like the wolf and the jackal, destroying not only hogs, but the calves and foals of the wild cattle and horses.

Besides the quadrupeds above enumerated, our domestic fowls have also thriven in the West Indies and America, where they have now the common fowl, the goose, the duck, the peacock, the pigeon, and the guinea-fowl. As these were often taken suddenly from the temperate to very hot regions, they were not reared at first without much difficulty; but after a few generations, they became habituated to the climate, which, in many cases, approached much nearer than that of Europe to the temperature of their original native countries. The fact of so many millions of wild and tame individuals of our domestic species, almost all of them the largest quadrupeds and birds, having been propagated throughout the new continent within the short period that has elapsed since the discovery of America, while no appreciable improvement can have been made in the productive powers of that vast continent, affords abundant evidence of the extraordinary changes which accompany the diffusion and progressive advancement of the human race over the globe.

Power of exterminating species no prerogative of man.—When we reflect how many millions of square miles of the fertile land, occupied originally by a boundless variety of animal

and vegetable forms, have been already brought under the dominion of man, and compelled, in a great measure, to yield nourishment to him, and to a limited number of plants and animals which he has caused to increase, we must at once be convinced, that the annihilation of a multitude of species has already been effected, and will continue to go on hereafter, in certain regions, in a still more rapid ratio, as the colonies of highly civilised nations spread themselves over unoccupied lands.

Yet, if we wield the sword of extermination as we advance, we have no reason to repine at the havoc committed, nor to fancy, with the Scottish poet, that 'we violate the social union of nature;' or complain, with the melancholy Jaques, that we

> Are mere usurpers, tyrants, and what's worse,
> To fright the animals and to kill them up
> In their assign'd and native dwelling-place.

We have only to reflect, that in thus obtaining possession of the earth by conquest, and defending our acquisitions by force, we exercise no exclusive prerogative. Every species which has spread itself from a small point over a wide area must, in like manner, have marked its progress by the diminution or the entire extirpation of some other, and must maintain its ground by a successful struggle against the encroachments of other plants and animals. That minute parasitic plant, called 'the rust' in wheat, has, like the Hessian fly, the locust, and the aphis, caused famines ere now amongst the 'lords of the creation.' The most insignificant and diminutive species, whether in the animal or vegetable kingdom, have each slaughtered their thousands, as they disseminated themselves over the globe, as well as the lion, when first it spread itself over the tropical regions of Africa.

Concluding remarks on extinction.—From what has now been said of the effect of changes which are always going on in the condition of the habitable surface of the globe, and the manner in which some species are constantly extending their range at the expense of others, it may be deduced, as a corollary, that the species existing at any particular period, may, in the course of ages, become extinct one after the

other. 'They must die out,' to borrow an emphatical ex pression from Buffon, 'because Time fights against them.'

If such then be a law of the organic world, if every species is continually losing some of its varieties and every genus some of its species, it follows that the transitional links which once, according to the doctrine of Transmutation, must have existed, will, in the great majority of cases, be missing. We learn from geological investigations that throughout an indefinite lapse of ages the whole animate creation has been decimated again and again. Sometimes a single representative alone remains of a type once dominant, or of which the fossil species may be reckoned by hundreds. We rarely find that whole orders have disappeared, yet even this is notably the case in the class of reptiles, which has lost some orders characterised by a higher organisation than any now surviving in that class. Certain genera of plants and animals which seem to have been wholly wanting, and others which were feebly represented, in the Tertiary Period, are now rich in species, and appear to be in such perfect harmony with the present conditions of existence, that they present us with countless varieties confounding the zoologist or botanist who undertakes to describe and classify them.

We have only to reflect on the causes of extinction enumerated in this chapter, and we at once foresee the time when even in these genera so many gaps will occur, so many transitional forms will be lost, that there will no longer be any difficulty in assigning definite limits to each surviving species. The blending therefore of one generic or specific form into another, must be an exception to the general rule, whether in our own times or at any period of the past, because the forms surviving at any given moment will have been exposed for a long succession of antecedent periods to those powerful causes of extinction which are slowly, but incessantly, at work in the organic and inorganic worlds.

Dr. Hooker, in commenting on the loss of a hundred species of plants in the course of the last three and a half centuries in St. Helena,* remarks, 'every one of these species was a

* See above, page 458.

link in the chain of created beings, which contained within itself evidence of the affinities of other species both living and extinct, but which evidence is now irrecoverably lost.'

It is affirmed by Darwin that genera which in the present state of the globe are most dominant contain also the most variable species. It is in such genera that the formation of new races, or 'incipient species,' is most actively going on; whereas in the majority of more ancient genera and families species are fast dying out; and that such has always been the order of Nature is proved by the fact, that while certain forms are characteristic of every geological period, these same are unknown or feebly represented, whether in older strata or in formations of later date.

They who imagine that if the theory of Transmutation be true we ought to discover in a fossil state all the intermediate links by which the most dissimilar types have been formerly connected together must tacitly assume that it is part of the plan of Nature to leave to after ages permanent records of all her works, whether animal or vegetable. Yet these same objectors to the theory would hardly expect that the species of plants just alluded to as having been so recently extirpated in St. Helena have all of them left memorials of their existence in the crust of the earth. In Chapter XIV. I have treated of the fragmentary nature of the geological record,* re-affirming what I first stated in 1833, that it is scarcely possible to exaggerate the defectiveness of our archives. These records, like the existing species, are constantly wasting away before our eyes, while new deposits, containing the partial memorials of the modern fauna and flora, are now in the process of formation. But as the new strata are deposited out of sight, chiefly in the basins of seas and lakes, their origin is not so conspicuous as is the destruction of the memorials of older date.

So also, as before stated (p. 270), the dying out of old forms is more easily proved than the coming in of new ones. We might see in a large forest a full-grown tree blown down or felled by the axe every day in the year, and yet at the end of fifty years

* Vol. I. pp. 314–320.

find that the number and size of the trees in the forest was the same as before, because the daily growth of timber spread over many thousands of trees, though insensible to the eye, may every day produce a quantity of foliage and timber equal in the aggregate to that contained in a single full-grown tree. In like manner if one species die out annually, as before hinted (p. 272), the loss may be compensated by the amount of permanent change effected by Variation and Natural Selection, in the course of a single year, among thousands of species.

CHAPTER XLIII.

MAN CONSIDERED WITH REFERENCE TO HIS ORIGIN AND GEOGRAPHICAL DISTRIBUTION.

GEOGRAPHICAL DISTRIBUTION OF THE RACES OF MAN—DRIFTING OF CANOES TO VAST DISTANCES—MAN, LIKE OTHER SPECIES, HAS SPREAD FROM A SINGLE STARTING-POINT, OR LIMITED AREA—WHETHER MAN'S BODILY FRAME BECAME MORE STATIONARY WHEN HIS MIND BECAME MORE ADVANCED—GREAT ANTIQUITY OF THE MORE MARKED HUMAN RACES—GENERAL COINCIDENCE OF THEIR RANGE WITH THE GREAT ZOOLOGICAL PROVINCES—AMERICAN-INDIAN COMMON TO NEOARCTIC AND NEOTROPICAL REGIONS—MAN AN OLD-WORLD TYPE—MARKED LINE OF SEPARATION BETWEEN MALAYAN AND PAPUAN RACES—DISTINCTNESS OF NEGRO AND EUROPEAN, AND QUESTION OF THE MULTIPLE ORIGIN OF MAN—SIX-FINGERED VARIETY OF MAN AS BEARING ON THE MUTABILITY OF HIS ORGANISATION—REGROWTH OF SUPERNUMERARY DIGITS WHEN AMPUTATED—THESE PHENOMENA REFERRED BY DARWIN TO REVERSION—WHETHER MAN HAS BEEN DEGRADED FROM A HIGHER OR HAS RISEN FROM A LOWER STAGE OF CIVILISATION—GRADUAL DIMINUTION OF THE NUMBER OF LANGUAGES AND RACES—GAUDRY ON INTERMEDIATE FORMS BETWEEN THE UPPER MIOCENE AND THE LIVING MAMMALIA—RELATIONSHIP OF MIOCENE AND LIVING QUADRUMANA—OWEN'S CLASSIFICATION OF MAMMALIA ACCORDING TO CEREBRAL DEVELOPMENT—PROGRESSIVE ADVANCEMENT IN CEREBRAL CAPACITY OF THE VERTEBRATA—IMPROVEMENT OF MAN'S CEREBRAL CONFORMATION—WHETHER THERE IS ANY FIXED LAW OF PROGRESS—OBJECTIONS TO DARWIN'S THEORY OF NATURAL SELECTION CONSIDERED—GREAT STEP GAINED IF SPECIES ARE SHOWN TO BE DEVELOPED ACCORDING TO THE ORDINARY LAWS OF REPRODUCTION—CAUSE OF RELUCTANCE TO BELIEVE IN MAN'S DERIVATIVE ORIGIN.

Geographical distribution of the races of man—In this chapter I shall offer some observations on the geographical distribution of the different races of man, and consider whether if we admit the doctrine of Transmutation as most probable in the case of the inferior mammalia, we are bound to embrace the same hypothesis when speculating on the origin of the human species.

Long before the geologist had succeeded in tracing back the signs of man's existence to a time when Europe was inhabited by species of quadrupeds, such as the elephant,

rhinoceros, bear, lion, hyæna, and others long since extinct, naturalists had already amused themselves in speculating on the probable birthplace of mankind, the point from which, if we assume the whole human race to have descended from a single stock, the tide of emigration must originally have proceeded. It has been always a favourite conjecture, that this birthplace was situated in an island within or near the tropics, where perpetual summer reigns, and where fruits, herbs, and roots are plentifully supplied throughout the year. The climate of these regions, it has been said, is suited to a being born without any covering, and who had not yet acquired the arts of building habitations or providing clothes.

'The hunter state,' it has been argued, 'which Montesquieu placed the first, was probably only the second stage at which mankind arrived; since so many arts must have been invented to catch a salmon, or a deer, that society could no longer have been in its infancy when they came into use.' * When regions where the spontaneous fruits of the earth abound became overpeopled, men would naturally diffuse themselves over the neighbouring parts of the temperate zone; but a considerable time would probably elapse before this event took place; and it is possible, as a writer before cited observes, that in the interval before the multiplication of their numbers and their increasing wants had compelled them to emigrate, some arts to take animals were invented, but far inferior to what we see practised at this day among savages. As their habitations gradually advanced into the temperate zone, the new difficulties they had to encounter would call forth by degrees the spirit of invention, and the probability of such inventions always rises with the number of people involved in the same necessity.†

Sir Humphry Davy, although coinciding for the most part in the above views, has introduced one of the persons in his second dialogue, as objecting to the theory of the human race having gradually advanced from a savage to a civilised state, on the ground that 'the first man must have inevit-

* Brand's Select Dissert. from the Amœn. Acad., vol. i. p. 118. † Ibid.

ably been destroyed by the elements or devoured by savage beasts, so infinitely his superiors in physical force.' * But this difficulty had been met, as before stated, by assigning, as the original seat of man, some island within the tropics, free from large beasts of prey. Here man may have remained for a period, peculiar to a limited area, just as some of the large anthropomorphous species are now restricted to one tropical island. In such a situation, the new-born race might have lived in security, though far more helpless than the New Holland savages, and might have found abundance of vegetable food. Colonies may afterwards have been sent forth from this mother country, and then the peopling of the earth may have proceeded according to the hypothesis before alluded to.

In an early stage of society the necessity of hunting acts as a principle of repulsion, causing men to spread with the greatest rapidity over a country, until the whole is covered with scattered settlements. It has been calculated that 800 acres of hunting-ground produce only as much food as half an acre of arable land. When the game has been in a great measure exhausted, and a state of pasturage succeeds, the several hunter-tribes, being already scattered, may multiply in a short time into the greatest number which the pastoral state is capable of sustaining. The necessity, says Brand, thus imposed upon the two savage states, of dispersing themselves far and wide over the country, affords a reason why, at a very early period, the worst parts of the earth may have become inhabited.

But this reason, it may be said, is only applicable in as far as regards the peopling of a continuous continent; whereas the smallest islands, however remote from continents, have almost always been found inhabited by man. St. Helena, it is true, afforded an exception; for when that island was discovered in 1501, it was only inhabited by sea-fowl, and occasionally visited by seals and turtles.† The islands also of Madeira, Mauritius, Bourbon, Pitcairn, and Juan Fernandez, and those of the Galapagos Archipelago, one of which is 70 miles long, were uninhabited by man when first

* Sir H. Davy, Consolations in Travel, p. 74. † See p. 457.

discovered, as were also the Falkland Islands, which is still more remarkable, since they are together 120 miles in length by 60 in breadth, and abound in food fit for the support of man.

Drifting of canoes to vast distances.—Very few of the numerous coral islets and volcanos of the vast Pacific, capable of sustaining a few families of men, have been found untenanted; and we have, therefore, to enquire whence and by what means, if all the members of the great human family have had one common source, could those savages have migrated. Captain Cook, Mr. Forster, and others, have remarked that parties of savages in their canoes must have often lost their way, and must have been driven on distant shores, where they were forced to remain, deprived both of the means and of the requisite intelligence for returning to their own country. Thus Cook found on the island of Wateoo three inhabitants of Otaheite, who had been drifted thither in a canoe, although the distance between the two isles is 550 miles. In 1696, two canoes, containing thirty persons, who had left Ancorso, were thrown by contrary winds and storms on the island of Samar, one of the Philippines, at a distance of 800 miles. In 1721, two canoes, one of which contained twenty-four, and the other six persons, men, women, and children, were drifted from an island called Farroilep to the island of Guaham, one of the Marians, a distance of 200 miles.*

Kotzebue, when investigating the Coral Isles of Radack, at the eastern extremity of the Caroline Isles, became acquainted with a person of the name of Kadu, who was a native of Ulea, an isle 1,500 miles distant, from which he had been drifted with a party. Kadu and three of his countrymen one day left Ulea in a sailing boat, when a violent storm arose, and drove them out of their course: they drifted about the open sea for eight months, according to their reckoning by the moon, making a knot on a cord at every new moon. Being expert fishermen, they subsisted entirely on the produce of the sea; and when the rain fell, laid in as much fresh water as they had vessels to contain it. 'Kadu,'

* Malte-Brun's Geography, vol. iii. p. 419.

says Kotzebue, 'who was the best diver, frequently went down to the bottom of the sea, where it is well known that the water is not so salt, with a cocoa-nut shell, with only a small opening.'* When these unfortunate men reached the isles of Radack, every hope and almost every feeling had died within them; their sail had long been destroyed, their canoe had long been the sport of winds and waves, and they were picked up by the inhabitants of Aur in a state of insensibility; but by the hospitable care of those islanders they soon recovered, and were restored to perfect health.†

Captain Beechey, in his voyage to the Pacific, fell in with some natives of the Coral Islands, who had in a similar manner been carried to a great distance from their native country. They had embarked, to the number of 150 souls, in three double canoes, from Anaa, or Chain Island, situated about 300 miles to the eastward of Otaheite. They were overtaken by the monsoon, which dispersed the canoes; and after driving them about the ocean, left them becalmed, so that a great number of persons perished. Two of the canoes were never heard of; but the other was drifted from one uninhabited island to another, at each of which the voyagers obtained a few provisions; and at length, after having wandered for a distance of 600 miles, they were found and carried to their home in the Blossom.‡

Mr. Crawfurd informs me that there are several well-authenticated accounts of canoes having been drifted from Sumatra to Madagascar, and by such causes a portion of the Malayan language, with some useful plants, have been transferred to that island, which is principally peopled by negroes.

The space traversed in some of these instances was so great, that similar accidents might suffice to transport canoes from various parts of Africa to the shores of South America, or from Spain to the Azores, and thence to North America;

* Chamisso states that the water which they brought up was cooler, and *in their opinion*, less salt. It is difficult to conceive its being fresher near the bottom, except where submarine springs may happen to rise.

† Kotzebue's Voyage, 1815–1818. Quarterly Review, vol. xxvi. p. 361.

‡ Narrative of a Voyage to the Pacific, &c., in the years 1825, 1826, 1827, 1828, p. 170.

so that man, even in a rude state of society, is liable to be scattered involuntarily by the winds and waves over the globe, in a manner singularly analogous to that in which many plants and animals are diffused. We ought not, then, to wonder, that during the ages required for some tribes of the human race to attain that advanced stage of civilisation which empowers the navigator to cross the ocean in all directions with security, the whole earth should have become the abode of rude tribes of hunters and fishers. Were the whole of mankind now cut off, with the exception of one family, inhabiting the old or new continent, or Australia, or even some coral islet of the Pacific, we might expect their descendants, though they should never become more enlightened than the Australians, the South Sea Islanders, or the Esquimaux, to spread in the course of ages over the whole earth, diffused partly by the tendency of population to increase, in a limited district, beyond the means of subsistence, and partly by the accidental drifting of canoes by tides and currents to distant shores.

Man has spread from a single starting-point.—The close affinity of all the races of mankind in their bodily conformation and in their mental and moral attributes, and the manner in which the most divergent varieties intermarry and blend together, require us to believe that the species was essentially in all its characters what it now is before it began to be diffused in the manner above supposed. The more we study the relations of man to the rest of the organic world, the more complete do we find his subjection to the same general laws. If, therefore, we infer that every species of animal has had a single birthplace, it is natural to expect that we shall find that man is no exception to the rule, and that he also spread over all the continents and islands from a single starting-point. But it does not follow that all are descendants of a single pair. Indeed, if we embrace the doctrine of Transmutation, the process by which a new species comes into being is by no means simple, and it is not easy to form a precise idea of its elaboration during that period of transition when certain varieties tending in a given direction are repeatedly getting the better of others in the struggle for life.

Under the constant influence of the same external conditions, the characters of such varieties become intensified during many successive generations, and when at last they are fixed and permanent the ancestral type may have perished, or in some cases may survive in certain stations, the intermediate forms having been absorbed into one or other of the two extremes. During a period when the powers of Variation and Selection are so active, a considerable number of individuals closely allied in their organisation will intermarry freely and multiply within a limited geographical area, and will transmit the same peculiarities of bodily and mental structure to their offspring. When, by this process, a large homogeneous population has been formed, and their characters have become fixed by inheritance, it will be long before subsequent changes of climate, soil, food, and other conditions, and, in the case of man, customs and institutions, will cause any marked deviations from the normal type.

That it should be so difficult for us to picture to ourselves the manner in which a species may be elaborated by Variation and Selection, need not surprise us when we consider how hard it is to obtain a clear idea of the growth and establishment of a new language, even when we are sure that the same has originated only a few centuries before our time. In the case of the English tongue, for example, it would not be easy to fix upon the exact year or generation when it was formed, or to follow it through its various transitional phases when the Anglo-Saxon stock was becoming modified by incorporating into it French, Danish, and Latin terms and idioms, or when new modes of pronunciation were coming into vogue or new and original expressions invented. The unity and permanency of character which finally sprang out of the blending together of such heterogeneous materials is a singular phenomenon, and the want of pliancy of the same language when transplanted into distant regions is also remarkable. The modifiability of the language and its tendency to vary never cease, so that it would readily run into new dialects and modes of pronunciation if there were no communication with the mother country direct or indirect. In this respect its mutability will resemble that of species, and it can

no more spring up independently in separate districts than species can, assuming that these last are all of derivative origin.

Whether man's bodily frame became more stationary when his mind became more advanced.—Mr. Wallace, when commenting on the distinctness of the leading races of mankind, especially the Caucasian and Negro, and on the constancy of characters maintained by these last for 4,000 years as proved by old Egyptian paintings, suggests that at some former period man's corporeal frame must have been more pliant and variable than it is now; for according to the observed rate of fluctuation in modern times, scarcely any conceivable lapse of ages would suffice to give rise to such an amount of differentiation. He therefore concludes that when first the mental and moral qualities of man acquired predominance, variations in his bodily form ceased to be preserved and accumulated by Natural Selection, because he was enabled to meet all new exigencies springing out of new conditions of existence by inventing new weapons, by clothing himself and building houses to protect him against the inclemency of the weather, by making use of fire to render palatable and nutritious animal and vegetable substances, and above all by his powers of social combination. Instead of the form of his limbs being modified or acquiring more agility and strength, instead of his sight or hearing becoming more acute, his body would remain stationary while his intellectual faculties would continually improve.*

Before, however, we embrace the views here set forth, we must be sure that we are not underrating the vastness of the time which it may possibly have taken for races so different as the European and Negro to diverge from a common type. Broca, in his work on Anthropology, when speaking of the paintings preserved in Egyptian temples nearly 4,000 years old, says that, besides Negroes and Greeks, there are representations of Jews, Mongols, Hindoos, and natives of the valley of the Nile, proving that all these types were then as distinct as they are now. He nevertheless thinks that

* Human Races, &c. Anthropological Review, May 1864, p. clviii. Also, Contributions to Natural Selection, pp. 311–317.

climate, social condition, alimentation, and mode of life may have determined originally the diversity of races, although it is evident that three or four thousand years is but a minute fraction of the time required to bring about such wide divergence from a common parent stock.

Mr. C. L. Brace, in his answer to Mr. Wallace, has remarked that when members of the Anglo-Saxon race have in the course of the last two centuries colonised a distant country, they have, as in the United States of America, deviated in an appreciable degree from the original type, in spite of the frequent intermarriage of the new settlers with emigrants coming from the mother country. 'The form,' he says, 'has become more angular and muscular, the complexion darker, and the face longer and thinner. The intellectual and moral powers of the Anglo-American have not been deficient, and yet they have not preserved him from variation.' It is also very commonly asserted that in a few generations the English settlers in Australia have varied somewhat after the manner of the Anglo-Americans. Grant that even a slight change can be superinduced in two centuries, what may not thousands of centuries have effected when the new settlers were wandering into countries where the conditions were far more dissimilar than those of England, North Africa, and South Australia?

We may, however, concede to Mr. Wallace that when first mankind emerged from its primitive dwelling-place and began to people the unoccupied continents and islands, the formation of marked races may have proceeded at a somewhat faster rate than now. After having been for a long time as strictly confined to one district as are now the chimpanzee or orang-outang, being still in a state of ignorance and barbarism somewhat lower than that of the Australian savage or the Andaman islander, man may have spread in scattered hunter-tribes over new latitudes, often encountering very ungenial climates in regions where food was abundant. Under such circumstances the mortality of the population would be great, and Natural Selection very active in giving a preference to certain varieties over others. In Great Britain and Belgium it has been shown by statistical returns that about

one tenth of the population die before they are a month old, and one fourth in early childhood. If in the newly settled territories the transitions from the extremes of heat and cold were frequent, those individuals who had weak lungs would be the victims, whereas in other regions where the temperature was very equable throughout the year, the same persons might be the most healthy and most likely to grow up and become the progenitors of the race destined to people the newly occupied district. So of other variations—in some cases a darker skin, in others a lighter complexion, might be most favourable, but many generations must pass away before a combination of characters best suited to the surrounding conditions would be attained.

Coincidence of the range of the more marked human races with the great zoological provinces.—Professor Agassiz has called attention to the important fact, that each of the more marked races of the human family, such as the white race, the Chinese, the New Hollanders, the Malays, and the Negroes, is limited to some great zoological province. This circumstance, he remarks, shows most unequivocally the intimate relation existing between mankind and the animal kingdom in their adaptation to the physical world. The same naturalist, however, has scarcely laid sufficient stress on one marked exception to this rule, namely, that over the whole continent of America south of the Arctic zone (or the region which is inhabited by Esquimaux) all the numerous tribes of Red Indians have the same physical character and are of one and the same race.* Dr. Morton had already declared this to be the case after studying the craniological characters of the American Indians from Canada to Patagonia. Nevertheless this continent comprises two of the great zoological regions before defined (p. 337) as the Neoarctic and Neotropical. On independent grounds Mr. Henry W. Bates has arrived at the conclusion that the Red Indian must have immigrated in comparatively modern times into the hot regions of equatorial America. Even the European, he says, bears exposure to the sun or to unusually hot weather quite

* Agassiz, Diversity of Origin of the Human Races. Christian Examiner, July 1850.

as well as the Indians, while the Negro is far better suited to the same climate, for he escapes many epidemic diseases incidental to hot latitudes which cause great havoc among the Indians. The latter, according to Mr. Bates, lives as a stranger in his own country, the valley of the Amazons. His constitution was not originally fitted, and has not since his immigration become perfectly adapted, to the climate of tropical America.*

We have as yet no geological data to enable us to determine the relative antiquity of man in the Old and New Worlds. Some fossil remains of our species found in the valley of the Mississippi imply, if their geological position has been correctly ascertained, that man was contemporary with many extinct quadrupeds and inhabited that region before it underwent some of its latest geographical changes.† But as a matter of speculation, if we assume that mankind, like every other species, has had but one birthplace, and if we also suppose him to have been derived from some nearly allied prototype, we must incline to the belief that the peopling of America took place at a later period than that of the Old World; for man, as has been truly said, is an 'Old-World type,' his bodily structure, as before observed (p. 333), being closely related to that of the quadrumana of Africa and Asia, and differing widely from all the species of the Western Hemisphere. But the first settling of mankind in America, though a comparatively modern event, may still date back as far as the Paleolithic period of Western Europe. Some of the latest changes in the valley of the Mississippi and its tributaries may have taken place since the remains of man and of some extinct animals were buried in superficial deposits, yet throughout the period of these geographical changes the chain of the Andes may have been always continuous from Canada to Patagonia, and may have facilitated the spread of a single race from one end of the continent to the other.

Mr. Wallace in his memoir on Man in the Malay Archipelago,‡ has explained how nearly the line *a*, *b* (map, fig. 138,

* Bates, Naturalist on the Amazons, vol. ii. p. 200.

† Lyell, 'Antiquity of Man,' p. 200.

‡ Read at Brit. Assoc. Newcastle 1864. See also Malay Archipelago, chap. xl.

p. 350), which separates the regions of the Indian and the Australian faunas, agrees with the geographical boundary line *c*, *b* (ibid.) dividing the habitations of the Indo-Malayan and the Papuan races. He describes the typical Malayan race, found almost exclusively in the western half of the archipelago, as of a light reddish brown colour with a more or less olive tint, hair black and straight, the face almost destitute of beard, the stature below the average European, while the Papuan race is much darker, sometimes almost as black as the Negro, the hair growing in tufts and frizzly, the face adorned with a beard, the stature equal to that of the European. The intellectual and moral characteristics of the two races are also described as strongly contrasted. These Papuans are found in New Guinea, while the Malays inhabit Borneo, two large islands almost exactly agreeing in climate and physical features, and within 300 miles of each other, and yet in which there is a total diversity of animal productions as well as a marked distinctness in the races of man. If we assume that these two races came originally from a common stock, we must suppose that they have been each of them separately exposed for hundreds of generations to a distinctness of external conditions analogous to that which, according to the theory of Transmutation, has, in the course of a much longer period, produced the discordance of species observed in the Indian and Australian regions.

Distinctness of Negro and European, and question of multiple origin of man.—It must be admitted, however, that we cannot so easily account for the differentiation of the Papuan and the Malay races as we can understand how the Negro acquired characters so different from those of all other members of the human family. For the natural barriers of the Ethiopian province, with the ocean on three sides and the great desert (submerged in Pliocene times) on the fourth, may well be supposed to have cut off for an indefinite lapse of ages a barbarous population from all intercourse with the rest of mankind, and to have given to peculiar external conditions an opportunity of fixing certain variations and forming a race without parallel in other parts of the world. The divergence, indeed, of the Negro from the European in the colour of his skin,

the texture and mode of growth of his hair, his features, the proportions of his limbs, and the average size of the brain, has led some naturalists to maintain that he is more than a mere variety of mankind, and ought to rank as a separate species.

Professor Agassiz, without going so far, believes nevertheless that the parent stocks from which these and other leading varieties have descended were originally distinct. According to him, a great number of individuals of each of the principal races of man were called into being when the race was created possessing all those characters which their posterity afterwards inherited; just as the same author imagines that a great many representatives of each species of animal, especially of species having social habits, were created in large numbers, so as at once to people the whole region which they were destined to inhabit. This theory has at least the merit of being consistent with itself, and relieves the opponents of transmutation from the dilemma of explaining why, if so great a divergence from a parent type as that of the white man and negro can take place, a like modifiability should not be able, in the course of ages, to go a step farther, and give rise to differences of specific value. That the races of mankind should never have diverged so far as to become incapable of intermarrying and producing fertile offspring is quite intelligible, if we consider the manner in which tribe wars against tribe, and how the inhabitants of the temperate and colder regions have continually invaded and overpowered the more indolent and less progressive tenants of tropical latitudes. These conquests explain the blending at the point of contact of one race into another, which has led many naturalists to affirm that instead of the five principal types of Blumenbach, there are fifty, if not more than a hundred races, each of which has had its own Adam and Eve.

Six-fingered variety of man as bearing on the mutability of his organisation.—As to the supposed want of flexibility in the bodily structure of man ever since the Paleolithic period, we ought to bear in mind that according to the theory of transmutation we can only expect variations in those parts of his organisation to be perpetuated, the improvement of

which would be useful to the individual or tribe giving them an advantage in the struggle for life. We have seen (page 299), that the experiments of the breeder and horticulturist prove that one part of the organisation of an animal or plant may be greatly altered by selection, while other parts which are neglected remain unchanged or do not vary in a perceptible degree. But the organ the variation of which would be most important in the case of man is the brain, and it is on cerebral development that Natural Selection would operate most effectively. Before considering whether, in the course of thousands of generations, some favourable modifications may not have taken place in this organ, giving to one race an advantage over others, it may be well to allude to a singular deviation from the normal standard which has been observed in man, and some other of the mammalia, and which has deservedly attracted much attention. This deviation consists in the occurrence of six, instead of five digits, of which examples are found in the dog and the cat as well as in human beings. Mr. Darwin, after having tabulated the cases of 46 persons with extra digits on one or both hands or feet, which he found recorded in various works or which had been privately communicated to him, ascertained that in this number, 73 hands and 75 feet were thus affected, proving, in contradiction to previous opinions, that the hands are not more frequently affected than the feet. Professor Huxley cites in detail from Reaumur the case of a Maltese couple named Kelleia, who, having hands and feet constructed on the ordinary human model, had born to them a son, Gratio, who possessed six perfectly movable fingers on each hand, and six toes, not quite so well formed, on each foot. This son married a woman with the ordinary pentadactyle extremities, and of their children one had six fingers and six toes, and the others were of the normal type. The six-fingered son had three out of four of his children six-fingered. But what is more remarkable, two of Gratio's children of the normal type having married five-fingered wives or husbands, nevertheless reproduced in the next generation the six-fingered variety. Thus, although in each case one parent and sometimes both were five-fingered, the six-fingered variety per-

sisted down to the grandchildren of Gratio. If, observes Professor Huxley, some of these last had been matched with their cousins having the same abnormal structure, we cannot doubt that a six-fingered and six-toed race would have been perpetuated. In these cases it usually happens that the supernumerary digit is supported on a metacarpal bone, and furnished with all proper muscles, nerves, and vessels, being so perfect as to escape detection, unless the fingers are actually counted. Additional digits, says Darwin, have been observed in negroes as well as in the white races.

The frequent re-growth of supernumerary digits after they have been cut off is another extraordinary fact which must not be lost sight of by those who are disposed to speculate on the nature and cause of this phenomenon. In one instance, that of a person now living (1868), the additional finger, when the infant was about six weeks old, was removed at the joint, and as soon as the wound healed, the digit began to grow, on which the operation in about three months was repeated, when the finger was once more reproduced including a bone. In another example cited by Dr. Carpenter of a thumb double from the first joint, the lesser thumb, which was furnished with a nail, was removed, but it grew again and reproduced a nail.* Mr. Darwin regards these supernumerary digits in man as retaining to a certain extent an embryonic condition, and resembling in this respect the normal digits and limbs of the lower vertebrate classes which are so prone to reproduction. Spallanzani cut off the tail and legs of the same salamander six times successively, and Bonnet cut them off eight times, and they were always renewed. The pectoral and tail-fins of many freshwater fish having been cut off have been perfectly restored in about six weeks' time. Fishes have sometimes in their pectoral fins more than five, sometimes as many as twenty, metacarpal and phalangeal bones forming so many rays, and occasionally bearing bony filaments, which together clearly represent our digits with their nails. So again in certain extinct reptiles, the Ichthyopterygia, 'the digits may be seven, eight, or nine in number, a significant

* Darwin, 'Variation,' vol. ii., p. 294.

mark,' says Professor Owen, 'of piscine affinity.'* Mr. Darwin therefore suggests that the excess in number and the power of re-growth of the supernumerary digits in man may be an instance of reversion to an enormously remote and multidigitate progenitor of very inferior grade.† As the number five is so strictly adhered to in the digits of all the higher vertebrata, and is at least never exceeded as a rule in any living reptile, bird, or mammal, the excess above alluded to in human digits is generally regarded as a monstrosity, the more so because, although six is the more common variety, yet there are sometimes from seven to more than ten fingers or toes, more or less perfect, on the same hand or foot, and occasionally less than five. Certainly this deviation from the ordinary standard, as well as the re-growth of the amputated limb, does not point in the direction of progressive improvement. If it be looked upon as a malformation occasionally shared by other mammalia, it only adds one more to innumerable other bonds of connection by which the inferior animals and man are united, whether in the perfection, or the occasional imperfection, of their organisation. One remarkable example of such bonds of affinity has been lately adduced by Mr. Darwin in his 'Descent of Man.' In the Quadrumana and Carnivora there is a passage near the lower end of the humerus, called the supra-condyloid foramen, through which the great nerve of the fore-limb passes, and often the great artery. Now occasionally this foramen occurs in man with the nerve passing through it, and it is remarkable that the percentage of the occurrence of this variation is greater in ancient than in modern races in the proportion of nearly 30 to 1. This has been ascertained by the examination of large numbers of arm-bones of the Bronze and Reindeer periods, and Mr. Darwin remarks, that one chief cause of this nearer approach of ancient races to the type of structure of the lower animals, seems to be 'that ancient races stand somewhat nearer in the long line of descent to their remote animal-like progenitors than do the modern races.' ‡

* Darwin, 'Variation,' vol. ii., p. 294.

† See above, p. 292, on Darwin's theory of Pangenesis.

‡ 'Descent of Man,' vol. i., p. 28.

Whether man has been degraded from a higher or has risen from a lower stage of civilisation.—All our recent investigations in Europe into the state of the arts in the earlier Stone age, lead clearly to the opinion that at a period many thousands of years anterior to the historical, man was in a state of great barbarism and ignorance, exceeding that of the most savage tribes of modern times. He was evidently ignorant of metals, and of the arts of polishing stone implements and of making pottery. Sir John Lubbock, in discussing the question whether our ancestors have been degraded from an original stock which was more highly advanced in knowledge and civilisation, or has risen from a lower state, observes that no fragment of pottery has been found among the natives of Australia, New Zealand, and the Polynesian islands, any more than ancient architectural remains, in all which respects these rude tribes now living resemble the men of the Paleolithic age. When pottery, he says, is known at all, it is always abundant, and though easy to break, it is difficult to destroy. It is improbable that so useful an art should ever have been lost by any race of man. The theory, therefore, that the savage races have been degraded from a previous state of civilisation may be rejected. 'Civilised nations long retain traces of their ancient barbarism, whereas barbarous ones retain no relics of a previous more advanced state. The stone knives used by the Egyptian and Jewish priests in religious ceremonies, after metal was in use for secular purposes, point to an antecedent period when such stone implements were in general use. They would long be regarded as sacred, and there would be a reluctance to use a new substance in religious ceremonies.' *

Some have wished to found an argument in favour of the superior mental endowments of the earliest races of mankind, by pointing out that the Sanscrit, and some others of the most ancient languages of Asia, are very artificial in their grammatical construction and rich in abstract terms. But the nations speaking these tongues will be regarded by every geologist as modern when compared to the men of the Paleolithic age. In tracing back the course of human events we

* On the Early Condition of Man, Sir John Lubbock. British Assoc. 1867.

should first find a period when scattered migratory hordes in the hunter state were spreading over Asia, and then a still anterior period when one small area of land (possibly now in great part submerged in the Indian or Pacific oceans) contained the primitive stock from which they all have ramified, and we may be sure, if the theory of transmutation be true, that such progenitors of mankind had a scantier vocabulary than the humblest savage known to us. They would have been unable to count as far as the fingers on one hand, and would not have invented a single term expressive of an abstract idea. When the first emigrants were spreading over a wide continent, they would separate into small communities, each of which would gradually acquire a language of its own, but as often as one tribe became more powerful than its neighbours, it would conquer them and absorb into itself those who were not exterminated, imposing its language on the conquered, yet sometimes borrowing from them some terms and expressions. It is found that the number of independent languages spoken in a continuous tract of land is great in proportion to the barbarism of the natives. Dominant tribes, as they multiply and advance in civilisation and power, spread a single language over a vast area. The Chinese for example, several thousand years before our time, constituting a third of the population of the globe, imposed on nearly the whole of their empire one language, though diverging, it is true, into many dialects. How long a time it required for one race thus to obtain supremacy over a large part of Asia, we know not, but we may look forward to the time when the Europeans, especially the Anglo-Saxon race, will in like manner spread over still larger areas, displacing the aboriginal tribes of America, and, like their predecessors the Red Indians, spreading from the Arctic Region to Patagonia, so that one race and perhaps one language may eventually prevail throughout the Neoarctic and Neotropical provinces before alluded to.

It may seem to us almost incredible now that the progress of the arts has given us such powers of locomotion, such facilities of traversing continents and circumnavigating the globe, to say nothing of exchanging ideas instantaneously

with the inhabitants of the remotest regions, that nations, even after they had advanced far in civilisation, could remain so isolated as we know them to have done. How the Greeks, for example, in spite of their extraordinary genius and their spirit of commercial enterprise, could have continued so ignorant of the geography of countries only a few hundred miles distant from the coasts of the Mediterranean and Black Seas. The superior power which science confers is always increasing in a geometrical ratio, so that the displacement of the weaker by the more civilised nations is accelerated to an extent without parallel in the history of the past. Hence in future there will be a greater blending of races, and a constant tendency towards the establishment of one race and one language throughout the globe. It seems probable that the divergence from a common stock reached its climax, physically and psychologically, in the formation of the Caucasian and Negro races. If, therefore, we consider this differentiation as amounting only to one of race, it seems to follow that two rational species descending from a common parentage cannot coexist on the globe. In embracing this conclusion, however, we are not precluded from entertaining the opinion that the descendants of the same rational progenitors, if compared at two very distant times, may differ as much as might entitle them to rank as distinct species.

M. Gaudry on intermediate forms between the Upper Miocene and living mammalia.—The relationship of man to a supposed antecedent species nearly allied in bodily structure, offers at present to the geologist a field of somewhat unprofitable speculation, so long as the Pliocene and Post-Pliocene formations of tropical Africa and India are still unexplored. We are only beginning, by aid of paleontology, to trace back the passage through a series of gradational forms from the living mammalia to those of the Pliocene and still older Miocene periods. But in this department of osteology, the evidence already obtained since the time of Cuvier, in favour of transmutation, is certainly very striking. By no naturalist has its bearing been more clearly pointed out than by M. Gaudry, who, under the influence of the great teachers

who preceded him, entered on the enquiry with a theoretical bias directly opposed to the conclusions which he now so ably advocates. In his luminous memoir on the fossil bones found at Pikermi, near Mount Pentelicus, fourteen miles east of Athens, he has pointed out the transition through many intermediate forms of Upper Miocene species to others of Pliocene and Post-Pliocene date, showing how each successive discovery has enabled us to bridge over many gaps which existed only twenty or thirty years ago. Having myself had the advantage of seeing the original specimens collected by this zealous geologist and now in the museum of Paris, and having had the connecting links supplied by species obtained from other parts of the world laid before me, I have been able the more fully to appreciate the force of the evidence appealed to in favour of transmutation. But all who study M. Gaudry's memoir may form an independent opinion for themselves, by a glance at the genealogical tables of certain family types, in which the gradation of Miocene through Pliocene and Post-Pliocene to living genera and species is traced.

In the list of proboscidians, for example, we behold chronologically arranged more than thirty distinct species, beginning with the mastodons of the Middle Miocene Period, found in France, and continued through those of the Upper Miocene of Ava, the Sewalik Hills, Pikermi, and Eppelsheim, to the Pliocene forms of Southern India, Italy, and England, where both the mastodons and elephants occur. Finally we are conducted to the Post-Pliocene or quaternary species of Europe and America, till we end with the two existing elephants of India and Africa. Again of the rhinoceros family, besides the five living species, fifteen extinct ones are enumerated, and in addition to these, some generic forms of older or Eocene date, belonging to the same great family. The fossil pedigree of the horse tribe is equally instructive, traced from the Middle and Upper Miocene Hipparion of France, Germany, Greece, and India, through the Pliocene and Post-Pliocene equine species of Europe, India, and America, to the living horse and ass. But the twelve equine species referred by Leidy to seven genera detected in the

valley of the Niobrara in Pliocene and Post-tertiary formations,* are omitted from this table as not having been yet described in sufficient detail, and they would certainly, if inserted in M. Gaudry's table, help to fill up many a hiatus between the forms which he has recognised. The pig family, as well as some carnivora, such as the hyæna, have also furnished ample materials in illustration of the same law of a gradual change of structure.

Even the quadrumana are beginning to afford proofs of the manner in which the existing apes have ramified from their extinct prototypes, although our information respecting them, whether from Pikermi or elsewhere, has been hitherto almost exclusively derived from extra-tropical latitudes, where there are now no living representatives of the order. Only fourteen species of the ape and monkey tribe have as yet been detected in a fossil state, and each of these has usually furnished but a few bones of its skeleton to the osteologist. Yet they have not failed to throw much light on the transmutation hypothesis. The Dryopithecus of the Miocene era of the south of France, though specifically distinct from any ape now existing, comes so near to the living Gibbon, or long-armed ape, as not to deserve, in Professor Owen's opinion, the separate generic rank assigned to it by Lartet. All the other fossils of Europe and Asia have an affinity to living species or genera of the Catarrhine division, and those of America, found in Brazilian caves, to the Platyrrhine.

As to the Mesopithecus of Pikermi, the skeleton is almost complete, more so than that of any other fossil ape yet brought to light. It differs generically from any living Indian form, not so much by presenting any novel features in its structure as by combining characters which now belong to two distinct Indian types. For, says M. Gaudry, one might say that the living Semnopitheci of India have borrowed their skulls from this Miocene type, while the living Macaci have borrowed from it their limbs. 'In how different a light,' exclaims this eminent paleontologist, 'does the question

* See above, p. 340.

of the nature of species now present itself to us from that in which it appeared only twenty years ago, before we had studied the fossil remains of Greece and the allied forms of other countries; how clearly do these fossil relics point to the idea that species, genera, families, and orders now so distinct, have had common ancestors!'—'The more we advance and fill up the gaps, the more we feel persuaded that the remaining voids exist rather in our knowledge than in nature. A few blows of the pickaxe at the foot of the Pyrenees, of the Himalaya, of Mount Pentelicus in Greece, a few diggings in the sandpits of Eppelsheim, or in the Mauvaises Terres of Nebraska, have revealed to us the closest connecting links between forms which seemed before so widely separated! How much closer will these links be drawn when paleontology shall have escaped from its cradle!'*

Many of the most cultivated literary critics, and some eminent mathematicians, have shown, in the discussions which have arisen on the origin of species, an entire incapability of weighing and appreciating the evidence for and against transmutation, and this chiefly for two reasons: first, they have never been called upon, as classifiers in natural history, practically to decide whether certain forms, fossil or recent, should rank as species or as mere varieties—a point on which the most eminent zoologists and botanists often disagree; secondly, they are quite unconscious of the fragmentary nature of the record with which the geologist has to deal.† To one who is not aware of the extreme imperfection of this record, the discovery of one or two missing links is a fact of small significance; but to those who are thoroughly imbued with a deep sense of the defectiveness of the archives, each new form rescued from oblivion is an earnest of the former existence of hundreds of species, the greater part of which are irrecoverably lost.

Progressive development in the cerebral conformation of the vertebrata, including man.—I have already remarked when combating the notion that man in his corporeal structure has arrived at a fixed and stationary condition, that we have

* Gaudry, Animaux Fossiles de Pikermi, 1866, p. 34.

† See above, Vol. I. p. 314.

no right to make such an assumption, until we have acquired a more definite idea of the number of centuries which it took for the most marked of the human races to diverge, in different directions, so far from a common type. The rate of change generally in the animal and vegetable kingdoms is slow and insensible, and naturalists have never yet witnessed the formation of any one of the wild races which they regard as mere geographical varieties. They know not how many thousand generations it may have required to produce such changes; but we cannot infer in their case, or in that of man, that the era of the immutability of species has arrived. If the organisation of man has been modified in comparatively modern times, it is probably, as before hinted, in his cerebral development that variation has been manifested.

Linnæus declared that he could not distinguish man generically from the ape, and Professor Owen has spoken of the 'all-pervading similitude of structure—every tooth, every bone, being strictly homologous'—yet the same great anatomist considers man's superior cerebral development as entitling him to be placed in a sub-class apart from all the other mammalia. He has proposed a new classification of the highest division of the vertebrata with reference to the characters of their brain, and its greater or less resemblance, in volume and structure, to that of man. Some have objected, not perhaps without reason, that every such attempt to classify the animate creation by reference to a single organ, or one set of characters, has failed, and that in order to obtain a natural system of arrangement, we must duly consider the combined claims of as large a part as possible of the whole organisation. Nevertheless the extent to which cerebral conformation, taken by itself, has enabled Professor Owen to place the genera and orders of mammalia in an ascending scale, shows how predominant is the importance of the brain, and the intimate connection of this mysterious organ with mental power. We see the monotremes (the Echidna and duck-mole) take the lowest place in the scale, followed by the marsupials, all having brains the most dissimilar in capacity and form from that of man; while the quadrumana take the highest place measured by the same

standard, the family to which the chimpanzee and gorilla belong being at the head of the long list of tabulated genera and orders. It will also be observed that the bats, instead of maintaining the leading position among the 'Primates' which they occupied in the Linnæan classification, are assigned to a different and inferior sub-class, far more in accordance with their relative intelligence.

If we go still farther and compare the mammalia with the fish, or the lowest class of the vertebrata, we find a continuance of the same descending scale in accordance with a diminution in the volume of brain, as well as in a lessened concentration of the nervous system in one part of the animal; for the farther we recede from the human type, the smaller is the proportionate quantity and weight of the brain as compared to the spinal marrow. It is true that in attempting to apply these rules in detail the anatomist is often at fault, because he finds that in any given group of animals the larger species have proportionately smaller brains, or, in other words, the mass of the brain does not increase in the same ratio as the general bulk of the animal. Still the general proposition before laid down holds good, that the degree of intelligence and mental power enjoyed by the inferior animals increases with the increase of their cerebral capacity, and with the resemblance in the structure of their brain to that of man.

If we take the Hottentot as the least advanced variety of the negro type, we find not only the volume of the brain to be far below that of the average of the European, but that the two hemispheres are more symmetrical, and that in this and every peculiarity in which it deviates from the Caucasian standard, it approaches nearer in character to the Simian brain. The theory therefore of progressive development and transmutation would lead us to anticipate that the human skull of the Paleolithic Period would prove to be more pithecoid than the cranium of any living race. Our data are as yet too scanty to allow of our drawing safe conclusions from the fossil remains of the era in question, for the Neanderthal skull may be an exceptional variety, as may some other remains of a somewhat ape-like character, lately brought to

light by M. Dupont from a deposit containing the relics of extinct mammalia in the Belgian caves. It may also be said that there is no reason why the Paleolithic cranium should be much if at all inferior to that of an Australian, for the state of the arts in the Paleolithic Period accords well with that phase of advancement which the Australian and some other savage tribes had reached when they first became known to Europeans.

In the ninth chapter of the first volume, a brief summary was given of the evidence in favour of the successive appearance in chronological order of fish, reptile, bird and mammal, and lastly among the mammalia, the coming in of those anthropomorphous species which most resemble man in structure. If we then regard the advent of man as the last and culminating point attained in this continuous series of developments, we may well imagine that, during the transition from the quadrumanous to the human organisation, the brain was that part which underwent the chief modification. And when its growth and improvement had once conferred on man a decided superiority over the brutes, it would continue to be the organ which would go on improving, so as to give one race an advantage over others in the struggle for life.

Even if the paleontologist had obtained fossil crania of an age immediately antecedent to the Paleolithic, it might be difficult for him to derive from them a knowledge of the successive steps made in an ascending scale, if, as some physiologists suspect, the quality of the brain has often more to do than its quantity with intellectual superiority. But although size alone may be no safe criterion of relative mental power, it is undeniable that the skulls of a hundred individuals of transcendent ability would exceed in their average dimensions the skulls of an equal number of persons of inferior mental power. Whether the brain, like any other organ, gains strength by exercise, and whether an improvement thus acquired in the intellectual faculties may be handed down to the offspring by inheritance, are still matters of controversy. But no one is disposed to dispute that if some modification of an organ, or instinct, be produced by what is called

'spontaneous variation,' there is a decided propensity in the new structure or attribute to perpetuate itself by inheritance, as in the case of the six-fingered variety of man, before mentioned (p. 481), or the stunted legs of the Ancon sheep (p. 314).

If, therefore, it be part of the plan of Nature that living beings should occasionally give birth to varieties in some slight degree more perfect in the specialisation of their parts and organs, or in the perfection of an organ, instinct, or mental faculty, than had been enjoyed by any of their predecessors, Natural Selection will ensure the eventual success of such individuals in the struggle for life. When Mr. Darwin says that he does not believe in a law of necessary development, he means that simple and unimproved structures may sometimes be best fitted for simple conditions of life, and that even a degradation instead of an advance in structure may occasionally be advantageous. Nevertheless, in the long run, there will be a tendency, in the higher and more perfect organisms, to survive and multiply, not at the expense of the lower, with most of whom they will never come into competition, but at the expense of those which are most nearly allied to them. The repeated failure of particular varieties having organs and attributes somewhat superior to those of any of their progenitors, by no means implies that the final predominance of such organisms is left to chance. It suffices that there should be a power in Nature, capable of giving rise to individuals in advance of all which have preceded them, and it then becomes simply a question of time how soon the more improved varieties will prevail. Their final success is certain, though many adverse circumstances may retard the rate of progress.

Suppose a human infant endowed with intellectual capacity superior to that of any one previously born into the world; it is as liable to be cut off in childhood as one less gifted, but it has also an equal chance of growing up, and if it attains maturity it will promote the advancement of the tribe to which it belongs, inventing perhaps some warlike weapon or better laws and institutions, and there will be a great probability of some of the children of such an individual inheriting an

amount of talent above the average of their generation. The more civilisation advances the less will mere bodily strength and acuteness of the senses confer social superiority. But still, as Darwin says, there is no fixed and necessary law of progress. The institutions of a country may be so framed that individuals possessing moderate or even inferior abilities may have the best chance of surviving. Thus the Holy Inquisition in Spain may for centuries carefully select from the thinking part of the population all men of genius, all who dare to question received errors and who have the moral courage to express their doubts, and may doom them by thousands to destruction, so as effectually to lower the general standard of intelligence. But such exceptional institutions will not arrest the onward march of the human race. They will only depress one nation, causing it to decline in knowledge, power, wealth, population, and political influence, and prepare for the day when it will be conquered by some other people in which freer scope has been given to intellectual progress.

Objections to Darwin's theory of Natural Selection.—The Duke of Argyll, in his work on the 'Reign of Law,' (1867,) has made some valuable criticisms on Mr. Darwin's theory of Natural Selection. After observing that we know nothing of the natural forces by which new forms of life are called into being, he says that if there were evidence that the new could be developed from the old, he cannot see why there should be any reluctance to admit the fact.* But he denies that sufficient evidence in support of such a theory has yet been adduced. The introduction, he admits, of new species 'to take the place of those which have passed away, is a work which has been not only so often but so continuously repeated that it does suggest the idea of having been brought about through the instrumentality of some natural process.'† This process, or 'the adaptation of forces which can compass the required modifications in animal structure in exact proportion to the need of them, is in the nature of creation.' But Mr. Darwin, he says, does not pretend to explain how new forms first appear, but only how when they have ap-

* Reign of Law, p. 227. † Ibid. p. 226.

peared they acquired a preference over others. He also reminds us that Mr. Darwin frankly confesses that our ignorance of the laws of variation is profound: yet, says the Duke, he seems sometimes to forget this and to speak of Natural Selection as if it could account for the origin of species, whereas, 'according to his own definition, it can do nothing except with the materials presented to its hands. It cannot select except among things open to selection. It can originate nothing; it can only pick out and choose among the things which are originated by some other law.'* To speak therefore of Natural Selection as 'producing' certain modifications of structure or new organs, and as 'adapting' them, is to ascribe to it results which it cannot bring about, and 'the cause of which we cannot even guess at.'†

To me it appears that these criticisms are fairly applicable to those passages in Mr. Darwin's 'Origin of Species,' in which Natural Selection is spoken of as capable of bringing about any amount of change in the organs of an animal provided a series of minute transitional steps can be pointed out by which the transmutation may have been effected. Thus, for example, if some one of the invertebrate animals has a membrane or tissue without a single nerve, yet sensitive to light, while another creature such as an eagle is furnished with a perfect eye in which there is an apparatus for concentrating the luminous rays, and for refracting pictures of external objects with optic nerves to convey these images to the brain, it is suggested that we may understand how this perfect organ may have been 'formed by Natural Selection' if we can only find in Nature a series of animals which have organs of vision exhibiting all the intermediate grades of structure between the two extreme forms above mentioned. But in reality it cannot be said that we obtain any insight into the nature of the forces by which a higher grade of organisation or instinct is evolved out of a lower one by becoming acquainted with a series of gradational forms or states, each having a very close affinity

* Reign of Law, p. 230. † Ibid. p. 254.

to the other. Even if we could discover geological evidence that every modification between a mere power of sensation like that of a sponge and the intelligence of an elephant had been represented by every intermediate degree of instinct and capacity, and that beings endowed with faculties more and more perfect had succeeded each other in chronological order according to their relative perfection, like the successive stages in the development of the embryo from a simple germ-cell to the infant mammifer, still the mystery of creation would be as great, and as much beyond the domain of science, as ever. It is when there is a change from an inferior being to one of superior grade, from a humbler organism to one endowed with new and more exalted attributes, that we are made to feel that, to explain the difficulty, we must obtain some knowledge of those laws of variation of which Mr. Darwin grants that we are at present profoundly ignorant.

Mr. Mivart in a more recent work (1871) on the 'Genesis of Species,' while he is in favour of the theory of Evolution as distinct from Special Creation, has made good use of his extensive knowledge of Natural History and Comparative Anatomy in adducing cases of structure, such as the baleen of the whale, the mammary glands of the mammalia, and the eyes and auditory organs of the cephalopoda, which seem to him to point to a limit of the power of Natural Selection and the intervention of some unknown law or laws of still higher generality. To all these Mr. Darwin has severally replied at some length in the sixth edition of the 'Origin of Species,' (1872,) and I cannot do better than refer the reader to that work. But as the independent development of a perfect eye in the cephalopoda and vertebrata was the difficulty which made most impression on me on first reading the 'Genesis of Species,' I will allude to it more especially. 'In the cuttle fish,' says Mr. Mivart, 'we find an eye even more completely constructed on the vertebrate type than is the ear. Sclerotic, retina, choroid, vitreous humour, lens, aqueous humour, all are present. The correspondence is wonderfully complete, and there can hardly be any hesitation in saying that, for such an exact, prolonged, and correlated

series of similar structures to have been brought about in two independent instances by merely indefinite and minute accidental variations, is an improbability which amounts practically to impossibility.' Yet these organs in the two types must have been developed in entire and complete independence one of the other, for it would be impossible to find a common ancestor without going back to some very simple form not yet provided with even the rudiments of vision. To this Mr. Darwin replies,* that there is hardly any real resemblance between the eyes of the cuttle-fish and vertebrates—the retina in the cephalopod being totally different, with an actual inversion of the elemental parts, and with a large nervous ganglion included within the membranes of the eye. At the same time he allows that both are formed of transparent tissue and furnished with a lens for throwing an image into a darkened chamber: this, however, he contends is accounted for by the necessary conditions of the formation of any organ of vision, and he cites Hensen as having shown in a recent memoir on the Cephalopod that the fundamental structure in that type of animal is so distinct that it is not a little difficult to decide how far even the same terms ought to be employed in describing the analogous points of structure of the eyes of the cephalopoda and vertebrata.

For my own part, while allowing that Mr. Mivart may have overstated the resemblance or identity of the organs of the two classes, it still appears to me that the objections alluded to by me in the 10th edition,† when commenting on the arguments brought forward in the 'Reign of Law,' are strengthened by Mr. Darwin's admission that certain common conditions in the external world have caused the cephalopoda to acquire a transparent tissue, a lens, and a darkened chamber strictly analogous to those in the eye of the vertebrate without derivation by inheritance from a common ancestor. Some geologists, when speculating on the co-existence ‡ of vertebrates, insects, and cephalopods

* 'Origin of Species,' 6th ed., p. 151, (1872).

† See p. 496, present volume.

‡ Vol. I. chap. ix.; and Student's Elements, p. 447.

in the Silurian strata, the oldest of which the fauna can be said to be extensively known to us, have dwelt on the small approach which we seem to have made in those ancient rocks to the beginning of organic life, assuming it to be necessary to suppose that there has been a regular gradation from the more simple to the most highly differentiated type. But the difficulty of so early a co-existence of the three types no longer exists when we admit that the highest parts of their organisation, which discharge the same functional duties in all three, have been independently superinduced by the action of outward conditions, and that we need not derive them by inheritance from some common starting-point.

Neither Mr. Mivart nor the Duke of Argyll, however, have by any means argued, like the majority of Mr. Darwin's opponents, as if nothing had been gained by the theory of Natural Selection, merely because this principle may have had functions assigned to it far higher than it can possibly discharge. The real question at issue—that on which the 'Origin of Species' has thrown so much light—is the same as that discussed by us in the last ten chapters. It is not whether we can explain the creation of species, but whether species have been introduced into the world one after the other, in the form of new varieties of antecedent organisms and in the way of ordinary generation, or have been called into being by some other agency, such as the direct intervention of the First Cause. Was Lamarck right, assuming progressive development to be true, in supposing that the changes of the organic world may have been effected by the gradual and insensible modification of older pre-existing forms? Mr. Darwin, without absolutely proving this, has made it appear in the highest degree probable, by an appeal to many distinct and independent classes of phenomena in natural history and geology, but principally by showing the manner in which a multitude of new and competing varieties are always made to survive in the struggle for life. The tenor of his reasoning is not to be gainsaid by affirming that the causes or processes which bring about the improvement or differentiation of organs, and the general advance of the

organic world from the simpler to the more complex, remain as inscrutable to us as ever.

When first the doctrine of the origin of species by transmutation was proposed, it was objected that such a theory substituted a material self-adjusting machinery for a Supreme Creative Intelligence. But the more the idea of a slow and insensible change from lower to higher organisms, brought about in the course of millions of generations according to a preconceived plan, has become familiar to men's minds, the more conscious they have become that the amount of power, wisdom, design, or forethought, required for such a gradual evolution of life, is as great as that which is implied by a multitude of separate, special, and miraculous acts of creation.

A more serious cause of disquiet and alarm arises out of the supposed bearing of this same doctrine on the origin of man and his place in nature. It is clearly seen that there is such a close affinity, such an identity in all essential points, in our corporeal structure and in many of our instincts and passions, with those of the lower animals—that man is so completely subjected to the same general laws of reproduction, increase, growth, disease, and death,—that if progressive development, spontaneous variation, and natural selection have for millions of years directed the changes of the rest of the organic world, we cannot expect to find that the human race has been exempted from the same continuous process of evolution. Such a near bond of connection between man and the rest of the animate creation is regarded by many as derogatory to our dignity. It certainly gives a rude shock to many traditional beliefs, and dispels some poetic illusions respecting an ideal genealogy which scarcely 'appeared less than archangel ruined.' But we have already had to exchange the pleasing conceptions indulged in by poets and theologians as to the high position in the scale of being held by our early progenitors, for more humble and lowly beginnings, the joint labours of the geologist and archæologist having left us in no doubt of the ignorance and barbarism of Paleolithic Man.*

* For remarks on Paleolithic Man see close of Chapter XLVII.

We are sometimes tempted to ask whether the time will ever arrive, when science shall have obtained such an ascendancy in the education of the millions, that it will be possible to welcome new truths, instead of always looking upon them with fear and disquiet, and to hail every important victory gained over error, instead of resisting the new discovery, long after the evidence in its favour is conclusive. The motion of our planet round the sun, the shape of the earth, the existence of the antipodes, the vast antiquity of our globe, the distinct assemblages of species of animals and plants by which it was successively inhabited, and lastly the antiquity and barbarism of Primeval Man, all these generalisations, when first announced, have been a source of anxiety and unhappiness. The future now opening before us begins already to reveal new doctrines, if possible more than ever out of harmony with cherished associations of thought. It is therefore desirable, when we contrast ourselves with the rude and superstitious savages who preceded us, to remember, as cultivators of science, that the high comparative place which we have reached in the scale of being has been gained step by step by a conscientious study of natural phenomena, and by fearlessly teaching the doctrines to which they point. It is by faithfully weighing evidence, without regard to preconceived notions, by earnestly and patiently searching for what is true, not what we wish to be true, that we have attained that dignity, which we may in vain hope to claim through the rank of an ideal parentage.

CHAPTER XLIV.

ENCLOSING OF FOSSILS IN PEAT, BLOWN SAND, AND VOLCANIC EJECTIONS.

DIVISION OF THE SUBJECT—IMBEDDING OF ORGANIC REMAINS IN DEPOSITS ON EMERGED LAND—GROWTH OF PEAT—SITE OF ANCIENT FORESTS IN EUROPE NOW OCCUPIED BY PEAT—BOG IRON-ORE—PRESERVATION OF ANIMAL SUBSTANCES IN PEAT—MIRING OF QUADRUPEDS—BURSTING OF THE SOLWAY MOSS—IMBEDDING OF ORGANIC BODIES AND HUMAN REMAINS IN BLOWN SAND—GREAT DISMAL SWAMP—MOVING SANDS OF AFRICAN DESERTS—BURIED TEMPLE OF IPSAMBUL IN EGYPT—DRIED CARCASSES IN THE SANDS OF THE DESERT—SAND-DUNES AND TOWNS OVERWHELMED BY SAND-FLOODS—IMBEDDING OF ORGANIC AND OTHER REMAINS IN VOLCANIC FORMATIONS ON THE LAND.

THE second branch of our enquiry, respecting changes of the organic world, relates to the processes by which the remains of animals and plants become fossil, or are buried in the earth by natural causes. M. Constant Prevost divided the effects of geological causes into two great classes: those produced during the submersion of land beneath the waters, and those which take place after its emersion. I shall consider, first, in what manner animal and vegetable remains become included and preserved in deposits on emerged land, or that part of the surface which is not *permanently* covered by water, whether of lakes or seas; secondly, the manner in which organic remains become imbedded in deposits of lakes and seas.

Under the first division, I shall treat of the following topics:—1st, the growth of peat, and the preservation of vegetable and animal remains therein; 2ndly, the burying of organic remains in blown sand; 3rdly, of the same in the ejections and alluviums of volcanos; 4thly, in alluviums generally, and in the ruins of landslips; 5thly, in the mud and stalagmite of caves and fissures.

Growth of peat, and preservation of vegetable and animal remains therein.—The generation of peat, when not completely under water, is confined to moist situations, where the temperature is low. It may consist of any of the numerous plants which are capable of growing in such *stations;* but a species of moss (*Sphagnum*) constitutes a considerable part of the peat found in marshes of the north of Europe; this plant having the property of throwing up new shoots in its upper part, while its lower extremities are decaying.* Reeds, rushes, and other aquatic plants may usually be traced in peat; and their organisation is often so entire that there is no difficulty in discriminating the distinct species.

In general, says Sir H. Davy, one hundred parts of dry peat contain from sixty to ninety-nine parts of matter destructible by fire; and the residuum consists of earths usually of the same kind as the substratum of clay, marl, gravel, or rock, on which they are found, together with oxide of iron. 'The peat of the chalk counties of England,' observes the same writer, 'contains much gypsum: but I have found very little in any specimens from Ireland or Scotland, and in general these peats contain very little saline matter.'† From the researches of Dr. MacCulloch, it appears that peat is intermediate between simple vegetable matter and lignite.‡

Peat is sometimes formed on a declivity in mountainous regions, where there is much moisture; but in such situations it rarely, if ever, exceeds four feet in thickness. In bogs, and in low grounds into which alluvial peat is drifted, it is found forty feet thick and upwards; but in such cases it generally owes one half of its volume to the water which it contains. It has seldom been discovered within the tropics, although Mr. Wallace informs me that there is often a great depth of soft peaty matter in the swampy forests of Borneo; and it rarely occurs in the valleys, even in the south of France and Spain. It abounds more and more, in proportion as we advance farther from the equator,

* For a catalogue of plants which form peat, see Rev. Dr. Rennie's Essays on Peat, p. 171; and Dr. MacCulloch's Western Isles, vol. i. p. 129.

† Irish Bog Reports, p. 209.

‡ System of Geology, vol. ii. p. 353.

and becomes not only more frequent but more inflammable in northern latitudes.*

The same phenomenon is repeated in the southern hemisphere. No peat is found in Brazil, nor even in the swampy parts of the country drained by the La Plata on the east side of South America, or in the island of Chiloe on the west; yet when we reach the 45th degree of latitude and examine the Chonos Archipelago or the Falkland Islands, and Tierra del Fuego, we meet with an abundant growth of this substance. Almost all plants contribute here by their decay to the production of peat, even the grasses; but it is a singular fact, says Mr. Darwin, as contrasted with what occurs in Europe, that no kind of moss enters into the composition of the South American peat, which is formed by many plants, but chiefly by that called by Brown *Astelia pumila*.†

I learnt from Dr. Forchhammer, in 1849, that water charged with vegetable matter in solution does not throw down a deposit of peat in countries where the mean temperature of the year is above 43° or 44° Fahrenheit. Frost causes the precipitation of such peaty matter, but in warm climates the attraction of the carbon for the oxygen of the air mechanically mixed with the water increases with the increasing temperature, and the dissolved vegetable matter or humic acid (which is organic matter in a progressive state of decomposition) being converted into carbonic acid, rises and is absorbed into the atmosphere, and thus disappears.

Extent of surface covered by peat.—There is a vast extent of surface in Europe covered with peat, which, in Ireland, is said to spread over a tenth of the whole island. One of the mosses on the Shannon is described as being fifty miles long, by two or three broad; and the great marsh of Montoire, near the mouth of the Loire, is mentioned by Blavier, as being more than fifty leagues in circumference. According to Rennie, many of these mosses of the north of Europe occupy the place of forests of pine and oak, which have,

* Rev. Dr. Rennie on Peat, p. 260.

† Darwin's Journal, p. 349; 2nd ed. p. 287.

many of them, disappeared within the historical era. Such changes are brought about by the fall of trees and the stagnation of water, caused by their trunks and branches obstructing the free drainage of the atmospheric waters, and giving rise to a marsh. In a warm climate, such decayed timber would immediately be removed by insects, or by putrefaction; but, in the cold temperature now prevailing in our latitudes, many examples are recorded of marshes produced in this manner. Thus, in Mar forest, in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, are said to have been soon immured in peat, formed partly out of their perishing leaves and branches, and in part from the growth of other plants. We are also told that the overthrow of a forest by a storm, about the middle of the seventeenth century, gave rise to a peat-moss near Lochbroom, in Ross-shire, and that, in less than half a century after the fall of the trees, the inhabitants dug peat there.* But the rate at which peat is known to form in places where its growth has been carefully noted by scientific observers, is so slow that it is necessary to receive these accounts with caution.

Nothing is more common than the occurrence of buried trees at the bottom of the Irish peat-mosses, as also in most of those of England, France, and Holland; and they have been so often observed with parts of their trunks standing erect, and with their roots fixed to the subsoil, that no doubt can be entertained of their having generally grown on the spot. They consist, for the most part, of the fir, the oak, and the birch: where the subsoil is clay, the remains of oak are the most abundant; where sand is the substratum, fir prevails. In the marsh of Curragh, in the Isle of Man, vast trees are discovered standing firm on their roots, though at the depth of eighteen or twenty feet below the surface. Some naturalists have desired to refer the imbedding of timber in peat-mosses to aqueous transportation, since rivers are well known to float wood into lakes; but the facts above mentioned show that, in numerous instances, such an hypothesis is inadmissible. It has, moreover, been observed,

* Rennie's Essays on Peat, p. 65.

that in Scotland, as also in many parts of the Continent, the largest trees are found in those peat-mosses which lie in low regions, and that the trees are proportionally smaller in those which lie at higher levels; from which fact De Luc and Walker have both inferred that the trees grew on the spot, for they would naturally attain a greater size in lower and warmer levels. The leaves, also, and fruits of each species, are continually found immersed in the moss along with the parent trees; as, for example, the leaves and acorns of the oak, the cones and leaves of the fir, and the nuts of the hazel.

Supposed recent origin of some peat-mosses.—In Hatfield Moss, in Yorkshire, which appears clearly to have been a forest eighteen hundred years ago, fir-trees have been found 90 feet long, and sold for masts and keels of ships; oaks have also been discovered there above 100 feet long. The dimensions of an oak from this moss are given in the Philosophical Transactions, No. 275, which must have been larger than any tree now existing in the British dominions.

In the same moss of Hatfield, as well as in that of Kincardine, in Scotland, and several others, Roman roads are said to have been found covered to the depth of eight feet by peat, and it has also been affirmed that all the coins, axes, arms, and other utensils found in British and French mosses, are Roman. But the more careful examinations made of late years of the deposits of peat about 30 feet thick at Amiens, Abbeville, and other places in the valley of the Somme, lead me to distrust the inferences formerly drawn as to the age of a large portion of the European peat, which has been supposed to be of later date than the time of Julius Cæsar. M. Boucher de Perthes ascertained that Gallo-Roman remains occur at Abbeville, in peat nearer the surface than the more ancient weapons called Celts of the Stone Period. The same antiquary also remarked that the depth at which Roman works of art are met with, is not always a sure test of age, because in some parts of the swamp, especially near the river, the peat is often so fluid that heavy substances may sink through it.* Recent re-

* See 'Antiquity of Man,' p. 110.

searches may be said to have demonstrated that no small part of the European peat is pre-Roman and belongs to the age of bronze instruments, and even in great part to the antecedent Neolithic Stone Period, of which more will be said in Chapter XLVII.

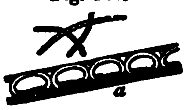
According to De Luc, the very sites of the aboriginal forests of Hercynia, Semana, Ardennes, and several others, are now occupied by mosses and fens. A great part of these changes have, with much probability, been attributed to the strict orders given by Severus, and other emperors, to destroy all the wood in the conquered provinces. So also many of the British forests, which are now mosses, were cut down at different periods, by order of the English parliament, because they harboured wolves or outlaws. Thus the Welsh woods were cut down and burnt, in the reign of Edward I.; as were many of those in Ireland, by Henry II., to prevent the natives from harbouring in them, and harassing his troops.

It is a remarkable fact, that in the Danish islands, and in Jutland as well as in Holstein, trunks of the Scotch fir, *Pinus sylvestris*, are found at the bottom of the peat-mosses, although this species of fir has not been a native of the same countries in historical times, and, when introduced there, has not thriven. Higher up in the Danish peat-mosses, prostrate trunks of the sessile variety of the common oak occur, while at a still higher level, the pedunculated variety of the same oak, *Quercus robur*, Linn., is met with, together with the alder, birch, and hazel. The oak has now in its turn been almost supplanted in Denmark by the common beech. There appears therefore to have been a natural rotation of trees in that country; one set of species, which lived on the borders of the swamps, having died out and another succeeded. These changes took place, all of them, before the historical era; but remains of man have been found even in the fundamental peat in which the Scotch firs lie buried, and a flint implement has been taken out, by Steenstrup himself, from below one of the buried pines. It was a weapon of the later Stone Period or Neolithic Age—no remains of Paleolithic Man having yet been discovered in any part of Scandinavia.*

* Lubbock, Introduction to Nilsson on the Stone Age, 1868.

Sources of bog iron-ore.—At the bottom of peat-mosses there is sometimes found a cake, or 'pan,' as it is termed, of oxide of iron, and the frequency of bog iron-ore is familiar to the mineralogist. The oak, which is so often dyed black in peat, owes its colour to the same metal. From what source the iron is derived has often been a subject of discussion, until the discoveries of Ehrenberg seem at length to have removed the difficulty. He had observed, in the marshes about Berlin, a substance of a deep ochre yellow passing into red, which covered the bottom of the ditches, and which, where it had become dry after the evaporation of the water, appeared exactly like oxide of iron. But under the microscope it was found to consist of slender articulated threads or plates, partly siliceous and partly ferruginous, of a plant of simple structure, *Gallionella ferruginea*, of the family called Diatomaceæ.* There can be little doubt, therefore, that bog iron-ore consists of an aggregate of millions of these organic bodies invisible to the naked eye.†

Fig. 145.



Gallionella ferruginea.
a. 2000 times magnified.

Preservation of animal substances in peat.—One interesting circumstance attending the history of peat-mosses is the high state of preservation of animal substances buried in them for periods of many years. In June, 1747, the body of a woman was found six feet deep, in a peat-moss in the Isle of Axholm, in Lincolnshire. The antique sandals on her feet afforded evidence of her having been buried there for many centuries; yet her nails, hair, and skin are described as having shown hardly any marks of decay. On the estate of the Earl of Moira, in the north of Ireland, a human body was dug up, a foot deep in gravel, covered with eleven feet of peat; the body was completely clothed, and the garments seemed all to be made of hair. Before the use of wool was known in that country the clothing of the inhabitants was made of hair, so that it would appear that this body had been buried at that early period; yet it was fresh and

* See above, Vol. I. p. 645.

† Ehrenberg, Taylor's Scientific Mem., vol. i. part iii. p. 402.

unimpaired.* In the Philosophical Transactions we find an example recorded of the bodies of two persons having been buried in moist peat, in Derbyshire, in 1674, about a yard deep, which were examined twenty-eight years and nine months afterwards; 'the colour of their skin was fair and natural, their flesh soft as that of persons newly dead.' †

Among other analogous facts we may mention, that in digging a pit for a well near Dulverton, in Somersetshire, many pigs were found in various postures, still entire. Their shape was well preserved, the skin, which retained the hair, having assumed a dry, membranous appearance. Their flesh was converted into a white, friable, laminated, inodorous, and tasteless substance; but which, when exposed to heat, emitted an odour precisely similar to that of broiled bacon.‡

We naturally ask whence peat derives this antiseptic property? It has been attributed by some to the carbonic and gallic acids which issue from decayed wood, as also to the presence of charred wood in the lowest strata of many peat-mosses, for charcoal is a powerful antiseptic, and capable of purifying water already putrid. Vegetable gums and resins also may operate in the same way. §

The tannin occasionally present in peat is the produce, says Dr. MacCulloch, of tormentilla, and some other plants; but the quantity he thinks too small, and its occurrence too casual, to give rise to effects of any importance. He hints that the soft parts of animal bodies, preserved in peat-bogs, may have been converted into adipocere by the action of water only. ‖

Miring of quadrupeds.—The manner, however, in which peat contributes to preserve, for indefinite periods, the harder parts of terrestrial animals, is a subject of more immediate interest to the geologist. There are two ways in which animals become occasionally buried in the peat of marshy grounds; they either sink down into the semifluid mud,

* Dr. Rennie on Peat, p. 521; where several other instances are referred to.

† Phil. Trans. vol. xxxviii. 1734.

‡ Dr. Rennie on Peat, &c., p. 521.

§ Ibid. p. 531.

‖ Syst. of Geol. vol. ii. pp. 340—346.

underlying a turfy surface upon which they have rashly ventured, or, at other times, as we shall see in the sequel, a bog 'bursts,' and animals may be involved in the peaty alluvium.

In the extensive bogs of Newfoundland, cattle are sometimes found buried alive with only their heads and necks above ground; and after having remained for days in this situation, they have been drawn out by ropes and saved. In Scotland, also, cattle venturing on a 'quaking moss,' are often mired, or 'laired,' as it is termed; and in Ireland, Mr. King asserts that the number of cattle which are lost in sloughs is quite incredible.*

Solway Moss.—The description given of the Solway Moss will serve to illustrate the general character of these boggy grounds. That moss, observes Gilpin, is a flat area, about seven miles in circumference, situated on the western confines of England and Scotland. Its surface is covered with grass and rushes, presenting a dry crust and a fair appearance; but it shakes under the least pressure, the bottom being unsound and semifluid. The adventurous passenger, therefore, who sometimes in dry seasons traverses this perilous waste, to save a few miles, picks his cautious way over the rushy tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to desert this mark of security, it is possible he may never more be heard of.

'At the battle of Solway, in the time of Henry VIII. (1542), when the Scotch army, commanded by Oliver Sinclair, was routed, an unfortunate troop of horse, driven by their fears, plunged into this morass, which instantly closed upon them. The tale was traditional, but it is now so far authenticated, that a man and a horse, in complete armour, have been found by peat-diggers, in the place where it was always supposed the affair had happened. The skeleton of each was well preserved, and the different parts of the armour easily distinguished.' †

The same moss, on the 16th of December, 1772, having

* Phil. Trans. vol. xv. p. 949.

† Gilpin, Observ. on Picturesque Beauty, &c., 1772.

been filled like a great sponge with water during heavy rains, swelled to an unusual height above the surrounding country, and then burst. The turfy covering seemed for a time to act like the skin of a bladder retaining the fluid within, till it forced a passage for itself, when a stream of black half-consolidated mud began at first to creep over the plain, resembling, in the rate of its progress, an ordinary lava-current. No lives were lost, but the deluge totally overwhelmed some cottages, and covered 400 acres. The highest parts of the original moss subsided to the depth of about 25 feet; and the height of the moss, on the lowest parts of the country which it invaded, was at least 15 feet.

Bursting of peat-mosses.—An inundation in Sligo in January, 1831, affords another example of this phenomenon. After a sudden thaw of snow, the bog between Bloomfield and Geevah gave way; and a black deluge, carrying with it the contents of a hundred acres of bog, took the direction of a small stream and rolled on with the violence of a torrent, sweeping along heath, timber, mud, and stones, and overwhelming many meadows and much arable land. On passing through some boggy land, the flood swept out a wide and deep ravine, and part of the road leading from Bloomfield to St. James's Well was completely carried away from below the foundation for the breadth of 200 yards.

An ancient log-cabin is recorded as having been found in 1833 at the depth of fourteen feet in the peat of Donegal. The cabin was filled with peat and was surrounded by other huts, which were not examined. The trunks and roots of trees preserved in their natural position surrounded these huts. There can be little doubt that we have here an example of a village which at some unknown period was overwhelmed by the bursting of a moss. In such cases the depth of vegetable matter which may overlie the dwelling affords no test of antiquity, as the whole thickness may have accumulated at once when the catastrophe occurred.

From the facts before mentioned, respecting the bursting of mosses and the manner in which they frequently descend in a fluid state to lower levels, the reader will readily perceive that lakes and arms of the sea must occasionally become the

receptacles of drift peat. Of this, accordingly, there are numerous examples; and hence the alternations of clay and sand with different deposits of peat so frequent on some coasts, as on those of the Baltic and German Ocean. We are informed by Deguer, that remains of ships, nautical instruments, and oars, have been found in many of the Dutch mosses. Gerard has shown by similar proofs that many mosses on the coast of Picardy, Zealand, and Friesland were at one period navigable arms of the sea.

Bones of herbivorous quadrupeds in peat.—The antlers of large and full-grown stags are amongst the most common and conspicuous remains of animals in peat. They are not horns which have been shed; for portions of the skull are found attached, proving that the whole animal perished. Bones of the ox, hog, horse, sheep, and other herbivorous animals, also occur. M. Morren discovered in the peat of Flanders the bones of otters and beavers,* and M. Boucher de Perthes found bones and teeth of the Ursus Arctos, or the bear which now lives in the Pyrenees, in the peat of Abbeville. But as a general rule no remains are met with belonging to extinct quadrupeds, such as the elephant, rhinoceros, hippopotamus, hyæna, and tiger, which are so common in old European river-gravels.

Bones of the mammoth mentioned by us in the first volume, pp. 549, 550, as occurring in peat and vegetable matter of older date than ordinary peat-mosses, are very exceptional. The great extinct deer also, Cervus Megaceros, has often been said to have been dug out of peat, but its true position seems to be in shell-marl underlying peat-mosses. The freshwater shells of such marl and others occasionally associated with peat, as well as the landshells met with in the same, are invariably of species now living.

Great Dismal Swamp.—I have described in my 'Travels in North America,'† an extensive swamp or morass, 40 miles long from north to south, and 25 wide, between the towns of Norfolk in Virginia, and Weldon in North Carolina. It is called the 'Great Dismal,' and has somewhat the

* Bulletin de la Soc. Géol. de France, tom. ii. p. 26.

† Travels, &c., in 1841, 1842, vol. i. p. 143.

appearance of an inundated river-plain covered with aquatic trees and shrubs, the soil being as black as that of a peat-bog. It is higher on all sides except one than the surrounding country, towards which it sends forth streams of water to the north, east, and south, receiving a supply from the west only. In its centre it rises 12 feet above the flat region which bounds it. The soil, to the depth of 15 feet, is formed of vegetable matter without any admixture of earthy particles, and offers an exception to a general rule before alluded to, namely, that such peaty accumulations scarcely ever occur so far south as lat. 36°, or in any region where the summer heat is so great as in Virginia. In digging canals through the morass for the purpose of obtaining timber, much of the black soil has been thrown out from time to time, and exposed to the sun and air, in which case it soon rots away so that nothing remains behind, showing clearly that it owes its preservation to the shade afforded by a luxuriant vegetation and to the constant evaporation of the spongy soil by which the air is cooled during the hot months. The surface of the bog is carpeted with mosses, and densely covered with ferns and reeds, above which many evergreen shrubs and trees flourish, especially the White Cedar (*Cupressus thyoides*), which stands firmly supported by its long tap roots in the softest parts of the quagmire. Over the whole the deciduous Cypress (*Taxodium distichum*) is seen to tower with its spreading top, in full leaf in the season when the sun's rays are hottest, and when, if not intercepted by a screen of foliage, they might soon cause the fallen leaves and dead plants of the preceding autumn to decompose, instead of adding their contributions to the peaty mass. On the surface of the whole morass lie innumerable trunks of large and tall trees blown down by the winds, while thousands of others are buried at various depths in the black mire below. They remind the geologist of the prostrate position of large stems of Sigillaria and Lepidodendron, converted into coal in ancient carboniferous rocks.

IMBEDDING OF HUMAN AND OTHER REMAINS, AND WORKS OF ART, IN BLOWN SAND.

The drifting of sand may next be considered among the causes capable of preserving organic remains and works of art on the emerged land.

African sands.—The sands of the African deserts have been driven by the west winds over part of the arable land of Egypt, on the western bank of the Nile, in those places where valleys open into the plain, or where there are gorges through the Libyan mountains. By similar sand-drifts the ruins of ancient cities have been buried between the temple of Jupiter Ammon and Nubia.

We have seen that Sir J. G. Wilkinson is of opinion that, while the sand-drift is making aggressions at certain points upon the fertile soil of Egypt, the alluvial deposit of the Nile is advancing very generally upon the desert; and that, upon the whole, the balance is greatly in favour of the fertilising mud.*

No mode of interment can be conceived more favourable to the conservation of monuments for indefinite periods than that now so common in the region immediately westward of the plain of the Nile. The sand which surrounded and filled the great temple of Ipsambul, first discovered by Burckhardt, and afterwards partially uncovered by Belzoni and Beechey, was so fine as to resemble a fluid when put in motion. Neither the features of the colossal figures, nor the colour of the stucco with which some were covered, nor the paintings on the walls, had received any injury from being enveloped for ages in this dry impalpable dust.†

At some future period, perhaps when the Pyramids shall have perished, changes in the surrounding sea and land may modify the climate and the direction of the prevailing winds, so that these may then waft away the Libyan sands as gradually as they once brought them to those regions, and may lay open to the day some of these buried temples.

* See Vol. I. p 430. † Stratton, Ed. Phil. Journ., No. v. p. 62.

Whole caravans are said to have been overwhelmed by the Libyan sands; and Burckhardt informs us that 'after passing the Akaba near the head of the Red Sea, the bones of dead camels are the only guides of the pilgrim through the wastes of sands.'—'We did not see,' says Captain Lyon, speaking of a plain near the Soudah mountains, in Northern Africa, 'the least appearance of vegetation; but observed many skeletons of animals, which had died of fatigue on the desert, and occasionally the grave of some human being. All these bodies were so dried by the heat of the sun, that putrefaction appears not to have taken place after death. In recently expired animals I could not perceive the slightest offensive smell; and in those long dead, the skin with the hair on it remained unbroken and perfect, although so brittle as to break with a slight blow. The sand-winds never cause these carcasses to change their places; for, in a short time, a slight mound is formed round them, and they become stationary.'*

Towns overwhelmed by sand floods.—The burying of several towns and villages in England, France, and Jutland, by blown sand is on record; thus, for example, near St. Pol de Leon, in Brittany, a whole village was completely buried beneath drift sand, so that nothing was seen but the spire of the church.† In Jutland marine shells adhering to sea-weed are sometimes blown by the violence of the wind to the height of 100 feet and buried in similar hills of sand.

In Suffolk, in the year 1688, part of Downham was overwhelmed by sands which had broken loose about 100 years before, from a warren five miles to the south-west. This sand had, in the course of a century, travelled four miles, and covered more than 1,000 acres of land.‡ A considerable tract of cultivated land on the north coast of Cornwall has been inundated by drift sand, forming hills several hundred feet above the level of the sea, and composed of comminuted marine shells, in which some terrestrial shells are enclosed entire. By the shifting of these sands the ruins of ancient

* Travels in North Africa in the Years 1818, 1819, and 1820, p. 83.

† Mém. de l'Acad. des Sci. de Paris, 1772. See also the case of the buried church of Eccles, Vol. I. p. 518.

‡ Phil. Trans. vol. iii. p. 722.

buildings have been discovered, among which is the church of St. Piran, in the parish of Perranzabuloe, or Perran in Sabulo, which I saw half exposed in 1870; and in some cases where wells have been bored to a great depth, distinct strata, separated by a vegetable crust, are visible. In some places, as at New Quay, large masses have become sufficiently indurated to be used for architectural purposes. The lapidification which is still in progress, appears to be due to oxide of iron held in solution by the water which percolates the sand.*

IMBEDDING OF ORGANIC AND OTHER REMAINS IN VOLCANIC FORMATIONS ON THE LAND.

I have in some degree anticipated the subject of this section in former chapters, when speaking of the buried cities around Naples, and those on the flanks of Etna.† From the facts referred to, it appeared that the preservation of human remains and works of art is frequently due to the descent of floods caused by the copious rains which accompany eruptions. These aqueous lavas, as they are called in Campania, flow with great rapidity; and in 1822 surprised and suffocated seven persons in the villages of St. Sebastian and Massa, on the flanks of Vesuvius.

In the tuffs, moreover, or solidified mud, deposited by these aqueous lavas, impressions of leaves and of trees have been observed. Some of those, formed after the eruption of Vesuvius in 1822, are now preserved in the museum at Naples.

Lava itself may become indirectly the means of preserving terrestrial remains, by overflowing beds of ashes, pumice, and ejected matter, which may have been showered down upon animals and plants, or upon human remains. Few substances are better non-conductors of heat than volcanic dust and scoriæ, so that a bed of such materials is rarely melted by a superimposed lava-current. After consolidation, the lava affords secure protection to the lighter and more removable

* Boase on Submersion of Part of the Mount's Bay, &c., Trans. Roy. Geol. Soc. of Cornwall, vol. ii. p. 140.

† Vol. I. p. 641, and Vol. II. p. 22.

mass below, in which the organic relics may be enveloped. The Herculanean tuffs containing the rolls of papyrus, of which the characters are still legible, have, as was before remarked, been for ages covered by lava.

Another mode by which lava may tend to the preservation of imbedded remains, at least of works of human art, is by its overflowing them when it is not intensely heated, in which case they sometimes suffer little or no injury.

Thus when the Etnean lava-current of 1669 covered fourteen towns and villages, and part of the city of Catania, it did not melt down coins and other articles in the vaults of Catania; and at the depth of 35 feet under the same current, on the site of Monpilere, one of the buried towns, the bell of a church and some statues were found uninjured (p. 24).

CHAPTER XLV.

BURYING OF FOSSILS IN ALLUVIAL DEPOSITS AND IN CAVES.

FOSSILS IN ALLUVIUM—EFFECTS OF SUDDEN INUNDATIONS—TERRESTRIAL ANIMALS MOST ABUNDANTLY PRESERVED IN ALLUVIUM WHERE EARTHQUAKES PREVAIL—MARINE ALLUVIUM—BURIED TOWNS—EFFECTS OF LANDSLIPS—ORGANIC REMAINS IN FISSURES AND CAVES—FORM AND DIMENSIONS OF CAVERNS—THEIR PROBABLE ORIGIN—CLOSED BASINS AND SUBTERRANEAN RIVERS OF THE MOREA—KATAVOTHRA—FORMATION OF BRECCIAS WITH RED CEMENT—HUMAN REMAINS IMBEDDED IN MOREA—SCHMERLING ON INTERMIXTURE OF HUMAN REMAINS AND BONES OF EXTINCT QUADRUPEDS AS PROVING THE FORMER CO-EXISTENCE OF MAN WITH THOSE LOST SPECIES—BONE-BRECCIAS FORMED IN OPEN FISSURES AND CAVES.

Fossils in Alluvium.—The next subject for our consideration, according to the division before proposed, is the imbedding of organic bodies in alluvium.

The gravel, sand, and mud in the bed of a river do not often contain any animal or vegetable remains; for the whole mass is so continually shifting its place, and the attrition of the various parts is so great, that even the hardest rocks contained in it are, at length, ground down to powder. But when sand and sediment are swept by a flood over lands bordering a river, such an alluvium may envelop trees or the remains of animals, which, in this manner, are often permanently preserved. In the mud and sand produced by the floods in Scotland, in 1829, the dead and mutilated bodies of hares, rabbits, moles, mice, partridges, and even the bodies of men, were found partially buried.* But in these and similar cases one flood usually effaces the memorials left by another, and it is only when rivers are eroding and deepening valleys that portions of old river channels are left high and dry beyond the reach of floods, in which case the organic remains may be preserved for ages.

* Sir T. D. Lauder, Bart., on Floods in Morayshire, Aug. 1829, p. 177.

In districts repeatedly deranged by earthquakes, rivers often shift their channels from one part of a valley to another, and alluvial accumulations caused by transient floods become permanent depositaries of organic substances.

Marine alluvium.—In May, 1787, a dreadful inundation of the sea was caused at Coringa, Ingeram, and other places, on the coast of Coromandel, in the East Indies, by a hurricane blowing from the NE., which raised the waters so that they rolled inland to the distance of about twenty miles from the shore, swept away many villages, drowned more than 10,000 people, and left the country covered with marine mud, on which the carcasses of about 100,000 head of cattle were strewed. An old tradition of the natives of a similar flood, said to have happened about a century before, was, till this event, regarded as fabulous by the European settlers.* The same coast of Coromandel was, so late as May, 1832, the scene of another catastrophe of the same kind; and when the inundation subsided, several vessels were seen grounded in the fields of the low country about Coringa.

Many of the storms termed hurricanes have evidently been connected with submarine earthquakes, as shown by the atmospheric phenomena attendant on them, and by the sounds heard in the ground and the odours emitted.

Houses and works of art in alluvial deposits.—A very ancient subterranean town, apparently of Hindoo origin, was discovered in India in 1833, in digging the Doab Canal. Its site is north of Saharunpore, near the town of Behat, and 17 feet below the present surface of the country. More than 170 coins of silver and copper were found, and many articles in metal and earthenware. The overlying deposit consisted of about 5 feet of river sand, with a substratum, about 12 feet thick, of red alluvial clay. In the neighbourhood are several rivers and torrents, which descend from the mountains charged with vast quantities of mud, sand, and shingle; and within the memory of persons now living the modern Behat has been threatened by an inundation, which, after retreating, left the neighbouring

* Dodsley's Ann. Regist., 1788.

country strewed over with a superficial covering of sand several feet thick. In sinking wells in the environs, masses of shingle and boulders have been reached resembling those now in the river-channels of the same district, under a deposit of thirty feet of reddish loam. Captain Cautley, therefore, who directed the excavations, supposes that the matter discharged by torrents has gradually raised the whole country skirting the base of the lower hills; and that the ancient town, having been originally built in a hollow, was submerged by floods, and covered over with sediment seventeen feet in thickness.*

We are informed by M. Boblaye, that in the Morea, the formation termed céramique, consisting of pottery, tiles, and bricks, intermixed with various works of art, enters so largely into the alluvium and vegetable soil upon the plains of Greece, and into hard and crystalline breccias which have been formed at the foot of declivities, that it constitutes an important stratum, which might, even in the absence of zoological characters, serve to mark part of the human epoch in a most indestructible manner.†

Landslips.—The landslip, by suddenly precipitating large masses of rock and soil into a valley, sometimes buries permanently whole villages, with their inhabitants and large herds of cattle and other animals. Thus three villages, with their entire population, were covered, when the mountain of Piz fell in 1772, in the district of Treviso, in the state of Venice,‡ and part of Mount Grenier, south of Chambery, in Savoy, which fell down in the year 1248, buried five parishes, including the town and church of St. André, the ruins occupying an extent of about nine square miles.§

The number of lives lost by the slide of the Rossberg, in Switzerland, in 1806, was estimated at more than 800, a great number of the bodies, as well as several villages and scattered houses, being buried deep under mud and rock. In the same country, several hundred cottages, with eighteen of their

* Journ. of Asiat. Soc., Nos. xxv. and xxix., 1834.

† Ann. des Sci. Nat., tom. xxii. p. 117, Feb. 1831.

‡ Malte-Brun's Geog., vol. i. p. 435.

§ Bakewell, Travels in the Tarentaise, vol. i. p. 201.

inhabitants and a great number of cows, goats, and sheep, were victims to the sudden fall of a bed of stones, thirty yards deep, which descended from the summits of the Diablerets in the Valais. In the year 1618, a portion of Mount Conto fell, in the district of Chiavenna, in Switzerland, and buried the town of Pleurs, with all its inhabitants, to the number of 2,430.

It is unnecessary to multiply examples of similar local catastrophes, which have been very numerous in mountainous parts of Europe, within the historical period, more especially in regions convulsed by earthquakes. It is where these occur that enormous masses of rock and earth, even in comparatively low and level countries, are detached from the sides of valleys, and cast down into the river courses, and often so unexpectedly that they overwhelm, even in the daytime, every living thing upon the plains.

PRESERVATION OF ORGANIC REMAINS IN FISSURES AND CAVES.

In the history of earthquakes it was shown that many hundreds of new fissures and chasms had opened in certain regions during the last 150 years, some of which are described as being of unfathomable depth. We also perceive that mountain masses have been violently fractured and dislocated, during their rise above the level of the sea; and thus we may account for the existence of many cavities in the interior of the earth by the simple agency of earthquakes; but there are some caverns, especially in limestone rocks, which, although usually, if not always, connected with rents, are nevertheless of such forms and dimensions, alternately expanding into spacious chambers, and then contracting again into narrow passages, that we cannot suppose them to have owed their origin exclusively to the mere fracturing and displacement of solid masses.

In the limestone of Kentucky, in the basin of Green River, one of the tributaries of the Ohio, a line of underground cavities has been traced in one direction for a distance of ten miles, without finding any termination; and one of the chambers, of which there are many, all connected by narrow

tunnels, is no less than ten acres in area, and 150 feet in its greatest height. Besides the principal series 'of antres vast,' there are a great many lateral embranchments not yet explored.*

The cavernous structure here alluded to is not altogether confined to calcareous rocks; for it has lately been observed in micaceous and argillaceous schist in the Grecian island of Thermia (Cythnos of the ancients), one of the Cyclades. Here also spacious halls, with rounded and irregular walls, are connected together by narrow passages or tunnels, and there are many lateral branches which have no outlet. A current of water has evidently at some period flowed through the whole, and left a muddy deposit of bluish clay upon the floor; but the erosive action of the stream cannot be supposed to have given rise to the excavations in the first instance. M. Virlet suggests that fissures were first caused by earthquakes, and that these fissures became the chimneys or vents for the disengagement of gas, generated below by volcanic heat. Gases, he observes, such as the muriatic, sulphuric, fluoric, and others, might, if raised to a high temperature, alter and decompose the rocks which they traverse. There are signs of the former action of such vapours in rents of the micaceous schist of Thermia, and thermal springs now issue from the grottos of that island. We may suppose that afterwards the elements of the decomposed rocks were gradually removed in a state of solution by mineral waters; a theory which, according to M. Virlet, is confirmed by the effect of heated gases which escape from rents in the isthmus of Corinth, and which have greatly altered and corroded the hard siliceous and jaspideous rocks.†

When we reflect on the quantity of carbonate of lime annually poured out by mineral waters, we are prepared to admit that large cavities must, in the course of ages, be formed at considerable depths below the surface in calcareous rocks.‡ These rocks, it will be remembered, are at once more soluble, more permeable, and more fragile, than any others,

* Nahum Ward, Trans. of Antiq. Soc. of Massachusetts. Holmes's United States, p. 438.

† Bull. de la Soc. Géol. de France tom. ii. p. 329.

‡ See above, Vol. I. p. 402.

at least all the compact varieties are very easily broken by the movements of earthquakes, which would produce only flexures in argillaceous strata. Fissures once formed in limestone are not liable, as in many other formations, to become closed up by impervious clayey matter, and hence a stream of acidulous water might for ages obtain a free and unobstructed passage.*

Morea.—Nothing is more common in limestone districts than the engulfment of rivers, which after holding a subterranean course of many miles escape again by some new outlet. As they are usually charged with fine sediment, and often with sand and pebbles where they enter, whereas they are commonly pure and limpid where they flow out again, they must deposit much matter in empty spaces in the interior of the earth. In addition to the materials thus introduced, stalagmite, or carbonate of lime, drops from the roofs of caverns, and in such mixture the bones of animals washed in by rivers are often entombed. In this manner we may account for those bony breccias which we often find in caves, some of which are of high antiquity while others are very recent and in daily progress. It is necessary to the formation of stalagmite that only so much water should be present as suffices to hold the carbonate of lime in solution. No deposit therefore takes place if a stream be continuously flowing through the cavern, and even if a coating be deposited during a season of drought this may easily be broken up again if changes in the underground drainage of the country or a rainy winter cause the cavern to be again flooded. For this reason we find broken up stalagmite occurring among the deposits of most caves, as in Kent's Hole and others. In no district are engulfed streams more conspicuous than in the Morea, where the phenomena attending them have been studied and described in great detail by M. Boblaye and his fellow-labourers of the French expedition to Greece.† Their account is peculiarly interesting to geologists, because it throws light on the red osseous breccias containing the bones of extinct quadrupeds which are so common in almost all the

* See remarks by M. Boblaye, Ann. des Mines, 3me série, tom. iv.

† Ann. des Mines, 3me série, tom. iv. 1833.

countries bordering the Mediterranean. It appears that the numerous caverns of the Morea occur in a compact limestone, of the age of the English chalk, immediately below which are arenaceous strata referred to the period of our greensand. In the more elevated districts of that peninsula there are many deep land-locked valleys, or basins, closed round on all sides by mountains of fissured and cavernous limestone. The year is divided almost as distinctly as between the tropics into a rainy season, which lasts upwards of four months, and a season of drought of nearly eight months' duration. When the torrents are swollen by the rains, they rush from surrounding heights into the enclosed basins; but, instead of giving rise to lakes, as would be the case in most other countries, they are received into gulfs or chasms, called by the Greeks 'Katavothra,' and which correspond to what are termed in England sink-holes or 'swallow-holes' in the chalk and limestone districts. The water of these torrents is charged with pebbles and red ochreous earth, resembling precisely the well-known cement of the osseous breccias of the Mediterranean. This deposit dissolves in acids with effervescence, and leaves a residue of hydrated oxide of iron, granular iron, impalpable grains of silex, and small crystals of quartz. Soil of the same description abounds everywhere on the surface of the decomposing limestone in Greece, that rock containing in it much siliceous and ferruginous matter.

Many of the Katavothra being insufficient to give passage to all the water in the rainy season, a temporary lake is formed round the mouth of the chasm, which then becomes still further obstructed by pebbles, sand, and red mud, thrown down from the turbid waters. The lake being thus raised, its waters generally escape through other openings, at higher levels, around the borders of the plain, constituting the bottom of the closed basin.

In some places, as at Kavaros and Tripolitza, where the principal discharge is by a gulf in the middle of the plain, nothing can be seen over the opening in summer, when the lake dries up, but a deposit of red mud, cracked in all directions. But the Katavothron is more commonly situated at the foot of the surrounding escarpment of limestone;

and in that case there is sometimes room enough to allow a person to enter, in summer, and even to penetrate far into the interior. Within is seen a suite of chambers, communicating with each other by narrow passages; and M. Virlet relates, that in one instance he observed, near the entrance, human bones imbedded in recent red mud, mingled with the remains of plants and animals of species now inhabiting the Morea. It is not wonderful, he says, that the bones of man should be met with in such receptacles; for so murderous have been the late wars in Greece, that skeletons are often seen lying exposed on the surface of the country.*

In summer, when no water is flowing into the Katavothron, its mouth, half closed up with red mud, is masked by a vigorous vegetation, which is cherished by the moisture of the place. It is then the favourite hiding-place and den of foxes and jackals; so that the same cavity serves at one season of the year for the habitation of carnivorous beasts, and at another as the channel of an engulfed river. Near the mouth of one chasm, M. Boblaye and his companions saw the carcass of a horse, in part devoured, the size of which seemed to have prevented the jackals from dragging it in: the marks of their teeth were observed on the bones, and it was evident that the floods of the ensuing winter would wash in whatsoever might remain of the skeleton.

It has been stated that the waters of all these torrents of the Morea are turbid where they are engulfed; but when they come out again, often at the distance of many leagues, they are perfectly clear and limpid, being only charged occasionally with a slight quantity of calcareous sand. The points of efflux are usually near the sea-shores of the Morea, but sometimes they are submarine; and when this is the case, the sands are seen to boil up for a considerable space, and the surface of the sea, in calm weather, swells in large convex waves. It is curious to reflect, that when this discharge fails in seasons of drought, the pressure of the sea may force its salt waters into subterraneous caverns, and carry in marine sand and shells, to be mingled with ossiferous mud, and the remains of terrestrial animals.

* Bull. de la Soc. Géol. de France, tom. iii. p. 223.

In general, however, the efflux of water at these inferior openings is constant and surprisingly uniform, seeming to prove that the caverns in the interior serve as reservoirs, and that the water escapes gradually from them, in consequence of the smallness of the rents and passages by which they communicate with the surface.

The phenomena above described are not confined to the Morea, but occur in Greece generally, and in those parts of Italy, Spain, Asia Minor, and Syria, where the calcareous formations of the Morea extend. The Copaic lake in Bœotia has no outlet, except by underground channels; and hence we can explain those traditional and historical accounts of its having gained on the surrounding plains and overflowed towns, as such floods must have happened whenever the outlet was partially choked up by mud, gravel, or the subsidence of rocks, caused by earthquakes. When speaking of the numerous fissures in the limestones of Greece, M. Boblaye reminds us of the famous earthquake of 469 B.C., when, as we learn from Cicero, Plutarch, Strabo, and Pliny, Sparta was laid in ruins, part of the summit of Mount Taygetus torn off, and numerous gulfs and fissures caused in the rocks of Laconia.

During the great earthquake of 1693, in Sicily, several thousand people were at once entombed in the ruins of caverns in limestone, at Sortino Vecchio; and, at the same time, a large stream, which had issued for ages from one of the grottos below that town, changed suddenly its subterranean course, and came out from the mouth of a cave lower down the valley, where no water had previously flowed. To this new point the ancient water-mills were transferred; as I learnt when I visited the spot in 1829.

When the courses of engulfed rivers are thus liable to change, from time to time, by alterations in the levels of a country, and by the rending and shattering of mountain masses, we must suppose that the dens of wild beasts will sometimes be inundated by subterranean floods, and their carcasses buried under heaps of alluvium. The bones, moreover, of individuals which have died in the recesses of caves, or of animals which have been carried in for prey, may be

drifted along, and mixed up with mud, sand, and fragments of rocks, so as to form osseous breccias.

In 1833 I had an opportunity of examining the celebrated caves of Franconia, and among others that of Rabenstein, then newly discovered. Their general form, and the nature and arrangement of their contents, appeared to me to agree perfectly with the notion of their having once served as the channels of subterranean rivers. This mode of accounting for the introduction of transported matter into the Franconian and other caves, filled up as they often are even to their roofs with osseous breccia, was long ago proposed by M. C. Prevost,* and seems at length to be very generally adopted. But I do not doubt that bears inhabited some of the German caves, or that the cavern of Kirkdale, in Yorkshire, was once the den of hyænas. The abundance of bony dung, associated with hyænas' bones, has been pointed out by Dr. Buckland, and with reason, as confirmatory of this opinion.

The same author observed in every cave examined by him in Germany, that deposits of mud and sand, with or without rolled pebbles and angular fragments of rock, were covered over with a *single* crust of stalagmite.† In the English caves he remarked a similar absence of *alternations* of alluvium and stalagmite. But Dr. Schmerling has discovered in a cavern at Chockier, about two leagues from Liege, three distinct beds of stalagmite, and between each of them a mass of breccia, and mud mixed with quartz pebbles, and in the three deposits the bones of extinct quadrupeds.‡

This exception does not invalidate the generality of the phenomenon pointed out by Dr. Buckland, one cause of which may perhaps be this, that if several floods pass at different intervals of time through a subterranean passage, the last, if it has power to drift along fragments of rock, will also tear up any alternating stalagmitic and alluvial beds that may have been previously formed. Another cause may be, that a particular line of caverns will rarely be sc

* Mém. de la Soc. d'Hist. Nat. de Paris, tom. iv.

† Reliquiæ Diluvianæ, p. 108.

‡ Journ. de Géol., tom. i. p. 286. July, 1830.

situated, in relation to the lowest levels of a country, as to become, at two distinct epochs, the receptacle of engulfed rivers.

As the same chasms may remain open throughout periods of indefinite duration, the species inhabiting a country may in the meantime be greatly changed, and thus the remains of animals belonging to very different epochs may become mingled together in a common tomb.

In several caverns on the banks of the Meuse, near Liege, Dr. Schmerling found human bones in the same mud and breccia with those of the elephant, rhinoceros, bear, and other quadrupeds of extinct species. He has observed none of the dung of any of these animals; and from this circumstance, and the appearance of the mud and pebbles, he concludes that these caverns were never inhabited by wild beasts, but that their remains were washed in by a current of water. As the human skulls and bones were in fragments, and no entire skeleton had been found, he does not believe that these caves were places of sepulture, but that the human remains were washed in at the same time as the bones of extinct quadrupeds, and that these lost species of mammalia coexisted on the earth with man.*

Bone-breccias formed in open fissures and caves.—Among the various modes in which the bones of animals become preserved independently of the agency of land floods and engulfed rivers, I may mention that open fissures often serve as natural pitfalls in which herbivorous animals perish. This may happen the more readily when they are chased by beasts of prey, or surprised while carelessly browsing on the shrubs which so often overgrow and conceal the edges of fissures.†

During the excavations recently made near Behat in India, the bones of two deer were found at the bottom of an ancient well which had been filled up with alluvial loam. Their horns were broken to pieces, but the jawbones and other

* The above was written in 1834, before the coexistence of man with the extinct animals had become a generally received doctrine. In my 'Antiquity of Man,' chap. iv., I have done more justice to Dr. Schmerling, and the reader will find there a full account of the Belgian caves which I re-examined in 1860.

† Buckland, Reliquiæ Diluvianæ, p.

parts of the skeleton remained tolerably perfect. 'Their presence,' says Captain Cautley, 'is easily accounted for, as a great number of these and other animals are constantly lost in galloping over the jungles and among the high grass by falling into deserted wells.'*

Above the village of Selside, near Ingleborough, in Yorkshire, a chasm of enormous but unknown depth occurs in the scar-limestone, a member of the carboniferous series. 'The chasm,' says Professor Sedgwick, 'is surrounded by grassy shelving banks, and many animals, tempted towards its brink, have fallen down and perished in it. The approach of cattle is now prevented by a strong lofty wall; but there can be no doubt that, during the last two or three thousand years, great masses of bony breccia must have accumulated in the lower parts of the great fissure, which probably descends through the whole thickness of the scar-limestone, to the depth of perhaps five or six hundred feet.'†

When any of these natural pitfalls happen to communicate with lines of subterranean caverns, the bones, earth, and breccia may sink by their own weight, or be washed into the vaults below.

At the north extremity of the rock of Gibraltar are perpendicular fissures, on the ledges of which a number of hawks nestle and rear their young in the breeding season. They throw down from their nests the bones of small birds, mice, and other animals on which they feed, and these are gradually united into a breccia of angular fragments of the decomposing limestone with a cement of red earth.

At the pass of Escrinet in France, on the northern escarpment of the Coiron hills, near Aubenas, I have seen a breccia in the act of forming. Small pieces of disintegrating limestone are transported, during heavy rains, by a streamlet, to the foot of the declivity, where landshells are very abundant. The shells and pieces of stone soon become cemented together by stalagmite into a compact mass, and the talus thus formed is in one place 50 feet deep, and 500 yards wide. So firmly

* See above, p. 520.

† On the Lake Mountains of North of England, Geol. Soc., Jan. 5, 1831.

is the lowest portion consolidated, that it is quarried for millstones.

Recent stalagmitic limestone of Cuba.—One of the most singular examples of the recent growth of stalagmitic limestone in caves and fissures, is that described by Mr. R. C. Taylor, as observable on the north-east part of the island of Cuba.* The country there is composed of a white marble, in which are numerous cavities, partially filled with a calcareous deposit of a brick-red colour. In this red deposit are shells, or often the hollow casts of shells, chiefly referable to eight or nine species of land snails, a few scattered bones of quadrupeds, and, what is still more singular, marine univalve shells, often at the height of many hundred, or even one thousand feet above the sea. The following explanation is given of the gradual increase of this deposit. Land snails of the genera Helix, Cyclostoma, Pupa, and Clausilia, retire into the caves, the floors of which are strewed with myriads of their dead and unoccupied shells, at the same time that water infiltered through the mountain throws down carbonate of lime, enveloping the shells, together with fragments of the white limestone which occasionally falls from the roof. Multitudes of bats resort to the caves; and their dung, which is of a bright red colour (probably derived from the berries on which they feed), imparts its red hue to the mass. Sometimes also the Hutia, or great Indian rat of the island, dies and leaves its bones in the caves. 'At certain seasons the soldier-crabs resort to the sea-shore, and then return from their pilgrimage, each carrying with them, or rather dragging, the shell of some marine univalve for many a weary mile. They may be traced even at the distance of eight or ten miles from the shore, on the summit of mountains 1,200 feet high, like the pilgrims of the olden times, each bearing his shell to denote the character and extent of his wanderings.' By this means several species of marine testacea of the genera Trochus, Turbo, Littorina, and Monodonta, are conveyed into inland caverns, and enter into the composition of the newly formed rock.

* Notes on Geol. of Cuba, 1836, Phil. Mag., July, 1837.

CHAPTER XLVI.

IMBEDDING OF ORGANIC REMAINS IN SUBAQUEOUS DEPOSITS.

DIVISION OF THE SUBJECT—IMBEDDING OF TERRESTRIAL ANIMALS AND PLANTS—INCREASED SPECIFIC GRAVITY OF WOOD SUNK TO GREAT DEPTHS IN THE SEA—DRIFT-TIMBER CARRIED BY THE MACKENZIE INTO SLAVE LAKE AND POLAR SEA—FLOATING TREES IN THE MISSISSIPPI—IN THE GULF-STREAM—ON THE COASTS OF ICELAND, SPITZBERGEN, AND LABRADOR—SUBMARINE FORESTS—EXAMPLES ON COAST OF HAMPSHIRE AND IN BAY OF FUNDY—MINERALISATION OF PLANTS—IMBEDDING OF INSECTS—OF REPTILES—BONES OF BIRDS WHY RARE—IMBEDDING OF TERRESTRIAL QUADRUPEDS BY RIVER FLOODS—SKELETONS IN RECENT SHELL-MARL—IMBEDDING OF MAMMALIAN REMAINS IN MARINE STRATA.

Division of the subject.—Having treated of the imbedding of organic remains in deposits formed upon the land, I shall next consider the including of the same in deposits formed under water.

It will be convenient to divide this branch of our subject into three parts; considering, first, the various modes whereby the relics of *terrestrial* species may be buried in subaqueous formations; secondly, the modes whereby animals and plants inhabiting *fresh water* may be so entombed; thirdly, how *marine* species may become preserved in new strata.

The phenomena above enumerated demand a fuller share of attention than those previously examined, since the deposits which originate upon dry land are insignificant in thickness, superficial extent, and durability, when contrasted with those of subaqueous origin. At the same time, the study of the latter is beset with greater difficulties; for we are here concerned with the results of processes much farther removed from the sphere of ordinary observation. There is, indeed, no circumstance which so seriously impedes the acquisition of just views in our science as an habitual disregard of the important fact, that the reproductive effects of the principal

agents of change are confined to another element—to that larger portion of the globe, from which, by our very organisation, we are almost entirely excluded.*

IMBEDDING OF TERRESTRIAL PLANTS.

When a tree falls into a river from the undermining of the banks or from being washed in by a torrent or flood, it floats on the surface, not because the woody portion is specifically lighter than water, but because it is full of pores containing air. When soaked for a considerable time, the water makes its way into these pores, and the wood becomes *water-logged* and sinks. The time required for this process varies in different woods; but several kinds may be drifted to great distances, sometimes across the ocean, before they lose their buoyancy.

If wood be sunk to vast depths in the sea, it may be impregnated with water suddenly. Captain Scoresby informs us, in his Account of the Arctic Regions, that on one occasion a whale, on being harpooned, ran out all the line in the boat, which it then dragged under water, to the depth of several thousand feet, the men having just time to escape to a piece of ice. When the whale returned to the surface 'to blow,' it was struck a second time, and soon afterwards killed. The moment it expired it began to sink—an unusual circumstance, which was found to be caused by the weight of the sunken boat, which still remained attached to it. By means of harpoons and ropes the fish was prevented from sinking, until it was released from the weight by connecting a rope to the lines of the attached boat, which was no sooner done than the fish rose again to the surface. The sunken boat was then hauled up with great labour; for so heavy was it, that although before the accident it would have been buoyant when full of water, yet it now required a boat at each end to keep it from sinking. 'When it was hoisted into the ship, the paint came off the wood in large sheets; and the planks, which were of wainscot, were as completely soaked in every pore as if they had lain at the bottom of the sea since the

* See above, Vol. I. p. 97.

flood! A wooden apparatus that accompanied the boat in its progress through the deep, consisting chiefly of a piece of thick deal, about fifteen inches square, happened to fall overboard, and though it originally consisted of the lightest fir, sank in the water like a stone. The boat was rendered useless; even the wood of which it was built, on being offered to the cook for fuel, was tried and rejected as incombustible.'*

Captain Scoresby found that, by sinking pieces of fir, elm, ash, &c. to the depth of 4,000 and sometimes 6,000 feet, they became impregnated with sea-water, and when drawn up again, after immersion for an hour, would no longer float. The effect of this impregnation was to increase the dimensions as well as the specific gravity of the wood, every solid inch having increased one-twentieth in size and about seven-eighths in weight.†

Drift-wood of the Mackenzie River.—When timber is drifted down by a river, it is often arrested by lakes; and, becoming water-logged, it may sink and be imbedded in lacustrine strata, if any be there forming; sometimes a portion floats on till it reaches the sea. In the course of the Mackenzie River in the north-western part of North America, we have an example of vast accumulations of vegetable matter now in progress under both these circumstances.

In Slave Lake in particular, which is 200 miles long, the quantity of drift-timber brought down annually is enormous 'As the trees,' says Sir John Richardson, 'retain their roots, which are often loaded with earth and stones, they readily sink, especially when water-soaked; and accumulating in the eddies, form shoals, which ultimately augment into islands. A thicket of small willows covers the new-formed island as soon as it appears above water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river; and it is interesting to study the diversity of appearances they present, according to their different ages. The trunks of the trees gradually decay until they are converted into a blackish-brown substance

* Account of the Arctic Regions, vol. ii. p. 193. † Ibid. p. 202.

resembling peat, but which still retains more or less of the fibrous structure of the wood; and layers of this often alternate with layers of clay and sand, the whole being penetrated, to the depth of four or five yards or more, by the long fibrous roots of the willows. A deposition of this kind, with the aid of a little infiltration of bituminous matter, would produce an excellent imitation of coal, with vegetable impressions of the willow-roots. What appeared most remarkable was the horizontal slaty structure that the old alluvial banks presented, and the *regular curve* that the strata assumed in places where there had been unequal subsidence.

'It was in the rivers only that we could observe sections of these deposits; but the same operation goes on, on a much more magnificent scale, in the lakes. A shoal of many miles in extent is formed on the south side of Athabasca Lake, by the drift-timber and vegetable débris brought down by the Elk River; and the Slave Lake itself must in process of time be filled up by the matters daily conveyed into it from Slave River. Vast quantities of drift-timber are buried under the sand at the mouth of the river, and enormous piles of it are accumulated on the shores of every part of the lake.'*

The banks of the Mackenzie display almost everywhere horizontal beds of wood coal, alternating with bituminous clay, gravel, sand, and friable sandstone; sections, in short, of such deposits as are now evidently forming at the bottom of the lakes which it traverses.

Notwithstanding that so much wood of the vast forests is intercepted by the lakes, a still greater mass of drift-wood is found where the Mackenzie reaches the sea, in lat. 69° N., where no wood grows at present except a few stunted willows. At the mouths of the river the alluvial matter has formed a barrier of islands and shoals, where we may expect a great formation of coal at some distant period.

The abundance of floating timber on the Mackenzie is owing to the direction and to the length of the course of this river, which runs from south to north, so that the sources of

* Sir J. Richardson's Geognost. Obs. on Capt. Franklin's Polar Expedition.

the stream lie in much warmer latitudes than its mouths. In the country, therefore, where the sources are situated, the frost breaks up at an earlier season, while yet the waters in the lower part of its course are ice-bound. Hence the current of water, rushing down northward, reaches a point where the thaw has not begun, and finding the channel of the river blocked up with ice, it overflows the banks, sweeping through forests of pines, and carrying away thousands of uprooted trees.

Drift-timber on coasts of Iceland, Spitzbergen, &c.—Although the Icelander can obtain no timber from the land, he is supplied with it abundantly by the ocean. An immense quantity of thick trunks of pines, firs, and other trees are thrown upon the northern coast of the island, especially upon North Cape and Cape Langanæs, and are then carried by the waves along these two promontories to other parts of the coast, so as to afford sufficiency of wood for fuel and for constructing boats. Timber is also carried to the shores of Labrador and Greenland; and Krantz assures us that the masses of floating wood thrown by the waves upon the island of John de Mayen often equal the whole of that island in extent.*

In a similar manner the bays of Spitzbergen are filled with drift-wood, which accumulates also upon those parts of the coast of Siberia that are exposed to the east, consisting of larch, pine, Siberian cedar, fir, and other kinds of trees, said to come from distant southern latitudes. Some of the trunks have been deprived of their bark by friction, but retain their roots and branches, and are in such a state of preservation as to form excellent building timber.† Parts of the branches and almost all the roots remain fixed to the pines which have been drifted into the North Sea, into latitudes too cold for the growth of such timber, but the trunks are usually barked.

The leaves and lighter portions of plants are seldom carried out to sea, in any part of the globe, except during tropical hurricanes among islands, and during the agitations of the

* Krantz, Hist. of Greenland, tom. i. pp. 53–54.

† Olafsen, Voyage to Iceland, tom. i.

atmosphere which sometimes accompany earthquakes and volcanic eruptions.

It will appear from these observations that, although the remains of terrestrial vegetation, borne down by aqueous causes from the land, are chiefly deposited at the bottom of lakes or at the mouths of rivers, yet a considerable quantity is drifted about in all directions by currents, and may become imbedded in any *marine* formation, or may sink down, when water-logged, to the bottom of the deepest abysses, and there accumulate.

It may be asked, whether we have any data for inferring that the remains of a considerable proportion of the existing species of plants will be permanently preserved, so as to be hereafter recognisable, supposing the strata now in progress to be at some future period upraised? To this enquiry it may be answered, that there are no reasons for expecting that more than a small number of the plants now flourishing on the globe will become fossilised; since the entire habitations of a great number of them are remote from lakes and seas, and even where they grow near to large bodies of water, the circumstances are quite accidental and partial which favour the imbedding and conservation of vegetable remains.

Submarine forest on coast of Hants.—Allusion has been made in the first volume, p. 548, to several localities on the British shores in which the remains of trees are seen in a vertical position submerged beneath the mean level of the sea, often with their roots attached. In many instances it is impossible to explain their submergence without assuming a change to have taken place in the relative level of land and sea. But such an hypothesis does not seem necessary in the case about to be described. My friend the Hon. Charles Harris—now Bishop of Gibraltar—discovered, in 1831, evident traces of a fir-wood beneath the mean level of the sea, at Bournemouth, in Hampshire, the formation having been laid open during a low spring tide. It is situated between the beach and a bar of sand about 200 yards off, and extends 50 yards along the shore, cropping out from beneath a bed of sand and shingle. It also lies in the

direct line of the Bournemouth Valley, from the termination of which it is separated by 200 yards of shingle and drift-sand. Down the valley flows a large brook, traversing near its mouth a considerable tract of rough, boggy, and heathy ground, which produces a few birch trees, and a great abundance of the bog-myrtle (*Myrica gale*). In that part of the submerged peat which was exposed at low water were seen twenty or more large stumps of fir, from one to two feet in height, the roots and bases of which still retain their bark. The sap-wood of these is soft and spongy, but perfectly white, and exhibiting its original character. The heart-wood is exceedingly hard and tough, and in the larger stumps, of a greenish hue, saturated with moisture, and exhaling a strong odour of sulphuretted hydrogen. 'This odour, and the greenish colour, are dependent,' says Bishop Harris, 'on an incipient formation of iron pyrites, which is proceeding with some rapidity in the peaty stratum beneath. The pyrites occurs in small concretions, enclosing both roots and fibres. In some instances it may be seen filling up the hollow stems of grasses, in others it has penetrated to the heart of pieces of fir-wood, two or three inches in diameter, following the grain of the wood and often supplying its place, so as not to be easily perceivable till broken.'

Seventy-six rings of annual growth were counted in a transverse section of one of the trees, which was fourteen inches in diameter. Besides the stumps and roots of fir, rushes, and other compressed vegetable matter and pieces of alder and birch, are found in the peat. In the centre of the formation the peat was pierced two feet and a half without being passed through; towards its edges, however, it is seen resting on a stratum of bluish pebbles, clay and sand, which crops out also on its seaward side, and is precisely similar to the sand and pebbles that occur on the adjoining heaths. The whole formation was shown to have existed 40 years before, in the same situation and presenting the same appearances as in 1831, and I learned from Bishop Harris (Feb. 1868) that on several occasions he had since revisited the spot and again observed the stumps *in situ*.

Now as the sea is encroaching on this shore, we may

suppose that at some former period the Bournemouth Valley extended farther, and that its extremity consisted, as at present, of rough and boggy ground, partly clothed with fir-trees. It is also probable that the whole of this rested on the sand and pebbles already mentioned, and that the sea, in its progressive encroachments, eventually laid bare, at low water, the foundations of this marshy ground; in which case, much of the sand constituting these foundations might have been washed out by the rapid descent of the fresh water through them at the fall of the tide. The superstratum of vegetable matter being matted and bound together by the roots of trees, would not be washed away, but might be undermined, and thus sink down below the level of the sea, until the waves washed sand and shingle over it. This operation may have also been assisted by the occasional damming up of the brook by the sand and shingle thrown up during storms. Bishop Harris informs me that such an obstruction actually occurred in the years 1818 and 1824, and the bed of the brook was completely obliterated. On these occasions an artificial channel was immediately cut; had this, however, not been done, the lower part of the valley would have been flooded; and by this means the under strata would have become more saturated with water, and the increased pressure would have augmented the tendency of the water to escape through them. In confirmation of this hypothesis we may observe, that small streams of fresh water often pass under the sands of the sea-beach, so that they may be crossed dryshod, whilst the water where it issues again may be seen to carry out sand and pebbles with great rapidity.

The Rev. W. B. Clarke, after examining the Bournemouth submarine peat and several other similar deposits on the north side of Poole Harbour, came, in 1838, to a conclusion, like that adopted by Bishop Harris and myself, that they had been sunk and submerged in modern times by the undermining of the sandy strata on which they rested, and did not imply a general subsidence or change of level in that part of the coast.*

* On Peat-bogs and Submarine Forests of Bournemouth. Rev. W. B. Clarke. Proc. of Geol. Soc. p. 599. 1838.

Submerged forest in Bay of Fundy.—One of the best authenticated examples of an old upland soil with trees, now covered by about thirty feet of water at high tide, occurs at Fort Lawrence in the Bay of Fundy, near the boundary between Nova Scotia and New Brunswick. Dr. Dawson, an experienced geologist and most careful observer, has shown that below layers of marine marsh-alluvium containing shells of *Sanguinolaria fusca,* (a bivalve shell probably identical with *Tellina Baltica,* Linn.,) there is a bed of tough blue clay, and beneath it an old peaty soil with erect trunks of trees and roots. All the stumps observed were those of pine and beech (*Pinus strobus* and *Fagus ferruginea*), trees indicative rather of dry upland than of swampy ground. The largest stump of a pine measured two and a half feet in diameter and exhibited about 200 rings of annual growth. Dr. Dawson counted thirty stumps in a limited area, and the same formation occurs at so many points as to lead him to infer that there has been a very general sinking down of the land in the same district. The powerful tides of the Bay of Fundy, rising and falling 40 feet, cause this formation to be peculiarly well exposed to view at many points, the deposit being laid bare by the continual encroachments of the sea.*

Mineralisation of plants.—Although the botanist and chemist have as yet been unable to explain fully the manner in which wood becomes petrified, it is nevertheless ascertained that, under favourable circumstances, the lapidifying process is now continually going on. A piece of wood was procured by Mr. Stokes, from an ancient Roman aqueduct in Westphalia, in which some portions were converted into spindle-shaped bodies, consisting of carbonate of lime, while the rest of the wood remained in a comparatively unchanged state.† It appears that in some cases the most perishable, in others the most durable, portions of plants are preserved, variations which doubtless depend on the time when the mineral matter was supplied. If introduced immediately,

* Dawson, Submerged Forest at Fort Lawrence, Quart. Geol. Journ., vol. xi. p. 119. 1854.

† Geol. Trans., second series, vol. v p. 212.

on the first commencement of decomposition, then the most destructible parts are lapidified, while the more durable do not waste away till afterwards, when the supply has failed, and so never become petrified. The converse of these circumstances gives rise to exactly opposite results.

Professor Göppert, of Breslau, has instituted a series of valuable experiments, in which he has succeeded in producing some very remarkable imitations of fossil petrifactions. He placed recent ferns between soft layers of clay, dried these in the shade, and then slowly and gradually heated them, till the clay was red-hot. The result was the production of so perfect a counterpart of fossil plants as might have deceived an experienced geologist. According to the different degrees of heat applied, the plants were obtained in a brown or perfectly carbonised condition; and sometimes, but more rarely, they were in a black shining state, adhering closely to the layer of clay. If the red heat was sustained until all the organic matter was burnt up, only an impression of the plant remained.

The same chemist steeped plants in a moderately strong solution of sulphate of iron, and left them immersed in it for several days, until they were thoroughly soaked in the liquid. They were then dried, and kept heated until they would no longer shrink in volume, and until every trace of organic matter had disappeared. On cooling them he found that the oxide formed by this process had taken the form of the plants. A variety of other experiments were made by steeping animal and vegetable substances in siliceous, calcareous, and metallic solutions, and all tended to prove that the mineralisation of organic bodies can be carried much farther in a short time than had been previously supposed.*

Imbedding of insects, reptiles, and birds.—I have observed the elytra and other parts of beetles in a band of fissile clay, separating two beds of recent shell-marl, in the Loch of Kinnordy in Forfarshire. Amongst these, Mr. Curtis recognised *Elater lineatus* and *Atopa cervina*, species still living in Scotland. These, as well as other remains which accompanied

* Göppert, Poggendorff's Annalen der Physik und Chemie, vol. xxxviii. part iv., Leipsic, 1836. See also Lyell's Student's Elements, p. 45.

them, appear to belong to terrestrial, not aquatic, species, and must have been carried down in muddy water during an inundation. In the lacustrine peat of the same locality, the elytra of beetles are not uncommon; but in the deposits of drained lakes generally, and in the silt of our estuaries, the relics of this class of the animal kingdom are rare. In the blue clay of very modern origin of Lewes Levels, Dr. Mantell has found the Indusia, or cases of the larvæ of Phryganea, in abundance, with minute shells belonging to the genera Planorbis, Limnea, &c., adhering to them.*

When speaking of the migrations of insects, I pointed out that an immense number are floated into lakes and seas by rivers, or blown by winds far from the land; but they are so buoyant that we can only suppose them, under very peculiar circumstances, to sink to the bottom before they are either devoured by insectivorous animals or decomposed.

As the bodies of several crocodiles were found in the mud brought down to the sea by the river inundation which attended an earthquake in Java, in the year 1699, we may imagine that extraordinary floods of mud may stifle many individuals of the shoals of alligators and other reptiles which frequent lakes and the deltas of rivers in tropical climates. Thousands of frogs were found leaping about among the wreck, carried into the sea by the inundations in Morayshire, in 1829;† and it is evident that whenever a sea-cliff is undermined, or land is swept by other violent causes into the sea, land reptiles may be carried in.

We might have anticipated that the imbedding of the remains of birds in new strata would be of very rare occurrence, for their powers of flight insure them against perishing by numerous casualties to which quadrupeds are exposed during floods; and if they chance to be drowned, or to die when swimming on the water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits. In consequence of the hollow tubular structure of their bones and the quantity of their feathers they are extremely light in proportion to their volume;

* Trans. Geol. Soc., vol. iii. part i. p. 201, second series.

† Sir T. D. Lauder's Account, 2nd ed., p. 312.

so that when first killed they do not sink to the bottom like quadrupeds, but float on the surface until the carcass either rots away or is devoured by predaceous animals. To these causes we may ascribe the absence of any vestige of the bones of birds in the recent marl formations of Scotland; although these lakes, until the moment when they were artificially drained, were frequented by a great abundance of water-fowl.

IMBEDDING OF TERRESTRIAL QUADRUPEDS.

River inundations recur in most climates at very irregular intervals, and expend their fury on those rich alluvial plains, where herds of herbivorous quadrupeds congregate together. These animals are often surprised; and, being unable to stem the current, are hurried along until they are drowned, when they sink at first immediately to the bottom. Here their bodies are drifted along, together with sediment, into lakes or seas, and may then be covered by a mass of mud, sand, and pebbles, thrown down upon them. If there be no sediment superimposed, the gases generated by putrefaction usually cause the bodies to rise again to the surface about the ninth or at latest the fourteenth day. The pressure of a thin covering of mud would not be sufficient to retain them at the bottom; for we see the putrid carcasses of dogs and cats, even in rivers, floating with considerable weights attached to them, and in sea-water they would be still more buoyant.

Where the body is so buried in drift-sand, or mud accumulated upon it, as never to rise again, the skeleton may be preserved entire; but if it comes again to the surface while in the process of putrefaction, the bones commonly fall piecemeal from the floating carcass, and may in that case be scattered at random over the bottom of the lake, estuary, or sea; so that a jaw may afterwards be found in one place, a rib in another, a humerus in a third—all included, perhaps, in a matrix of fine materials, where there may be evidence of very slight transporting power in the current, or even of none, but simply of some chemical precipitate.

A large number of the bodies of drowned animals, if they float into the sea or a lake, especially in hot climates, are

instantly devoured by sharks, alligators, and other carnivorous animals, which may have power to digest even the bones; but during extraordinary floods, when the greatest number of land animals are destroyed, the waters are commonly so turbid, especially at the bottom of the channel, that even aquatic species are compelled to escape into some retreat where there is clearer water lest they should be stifled. For this reason, as well as the rapidity of sedimentary deposition at such seasons, the probability of carcasses becoming permanently imbedded is considerable.

In some instances, the skeletons of quadrupeds are met with abundantly in recent shell-marls in Scotland, where we cannot suppose them to have been imbedded by the action of rivers or floods. They all belong to species which now inhabit, or are known to have been indigenous in Scotland. The remains of several hundred skeletons have been procured within the last century from five or six small lakes in Forfarshire, where shell-marl has been worked. Those of the stag (*Cervus Elaphus*) are most numerous; and if the others be arranged in the order of their relative abundance, they will follow nearly thus—the ox, the boar, the horse, the sheep, the dog, the hare, the fox, the wolf, and the cat. The beaver seems extremely rare; but it has been found in the shell-marl of Loch Marlie, in Perthshire, and in the parish of Edrom, in Berwickshire.

In the greater part of these lake-deposits there are no signs of floods; and the expanse of water was originally so confined, that the smallest of the above-mentioned quadrupeds could have crossed by swimming from one shore to the other. Deer, and such species as take readily to the water, may often have been mired in trying to land, where the bottom was soft and quaggy, and in their efforts to escape may have plunged deeper into the marly bottom. But many individuals, I suspect, of different species, have fallen in when crossing the frozen surface in winter; for nothing can be more treacherous than the ice when covered with snow, in consequence of the springs, which are numerous, and which, retaining always an equal temperature, cause the ice, in certain spots, to be extremely thin, while in every other

part of the lake it is strong enough to bear the heaviest weights.

Flood in the Solway Firth, 1794.—One of the most memorable floods of modern date, in our island, is that which visited part of the southern borders of Scotland, on the 24th of January, 1794, and which spread particular devastation over the country adjoining the Solway Firth.

We learn from the account of Captain Napier, that the heavy rains had swollen every stream which entered the Firth of Solway; so that the inundation not only carried away a great number of cattle and sheep, but many of the herdsmen and shepherds, washing down their bodies into the estuary. After the storm, when the flood subsided, an extraordinary spectacle was seen on a large sand-bank called 'the beds of Esk,' where there is a meeting of the tidal waters, and where heavy bodies are usually left stranded after great floods. On this single bank were found collected together the bodies of 9 black cattle, 3 horses, 1,840 sheep, 45 dogs, 180 hares, besides a great number of smaller animals, and, mingled with the rest, the corpses of two men and one woman.*

Floods in Scotland, 1829.—In those more recent floods in Scotland, in August, 1829, whereby a fertile district on the east coast became a scene of dreadful desolation, a vast number of animals and plants were washed from the land, and found scattered about after the storm, around the mouths of the principal rivers. An eye-witness thus describes the scene which presented itself at the mouth of the Spey, in Morayshire: —'For several miles along the beach crowds were employed in endeavouring to save the wood and other wreck with which the heavy-rolling tide was loaded; whilst the margin of the sea was strewed with the carcasses of domestic animals, and with millions of dead hares and rabbits.'†

Savannahs of South America.—We are informed by Humboldt, that during the periodical swellings of the large rivers

* Treatise on Practical Store Farming, p. 25.

† Sir T. D. Lauder's Floods in Morayshire, 1829; and above, Vol. I. p. 345.

in South America great numbers of quadrupeds are annually drowned. Of the wild horses, for example, which graze in immense troops in the savannahs, or level grassy plains, thousands are said to perish when the river Apure, a tributary of the Orinoco, is swollen, before they have time to reach the rising ground of the Llanos. The mares, during the season of high water, may be seen, followed by their colts, swimming about and feeding on the grass, of which the top alone waves above the waters. In this state they are pursued by crocodiles; and their thighs frequently bear the prints of the teeth of these carnivorous reptiles. 'Such is the pliability,' observes the celebrated traveller, 'of the organisation of the animals which man has subjected to his sway, that horses, cows, and other species of European origin, lead, for a time, an amphibious life, surrounded by crocodiles, water-serpents, and manatees. When the rivers return again into their beds, they roam in the savannah, which is then spread over with a fine odoriferous grass, and enjoy, as in their native climate, the renewed vegetation of spring.'*

Floods of the Paranà.—The great number of animals which are drowned in seasons of drought in the tributaries of the Plata was before mentioned. Sir W. Parish states that the Paranà flowing from the mountains of Brazil to the estuary of the Plata, is liable to great floods, and during one of these, in the year 1812, vast quantities of cattle were carried away, 'and when the waters began to subside, and the islands which they had covered became again visible, the whole atmosphere for a time was poisoned by the effluvia from the innumerable carcasses of skunks, capybaras, tigers, and other wild beasts which had been drowned.'†

Floods of the Ganges.—We find it continually stated, by those who describe the Ganges and Burrampooter, that these rivers carry before them, during the flood season, not only floats of reeds and timber, but dead bodies of men, deer, and oxen.‡

Java, 1699.—I have already referred to the effects of a flood which attended an earthquake in Java in 1699, when

* Humboldt's Pers. Nar., vol. iv. p. 394.

† Buenos Ayres and La Plata, p. 187.

‡ Malte-Brun, Geog., vol. iii. p. 22.

the turbid waters of the Batavian river destroyed all the fish except the carp; and when drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down to the sea-coast by the current, with several crocodiles which had been stifled in the mud. (See above, p. 159.)

On the western side of the same island, in the territory of Galongoon, in the Regencies, a more recent volcanic eruption (that of 1822, before described—see above, p. 57) was attended by a flood, during which the river Tandoi bore down hundreds of carcasses of rhinoceroses and buffaloes, and swept away more than 100 men and women from a multitude assembled on its banks to celebrate a festival. Whether the bodies reached the sea, or were deposited, with drift matter, in some of the large intervening alluvial plains, we are not informed.*

Sumatra.—'On the coast of Orissa,' says Heynes, 'I have seen tigers and whole herds of black cattle carried along by what are called freshes, and trees of immense size.'†

Virginia, 1771.—I might enumerate a great number of local deluges that have swept through the fertile lands bordering on large rivers, especially in tropical countries, but I should surpass the limits assigned to this work. I may observe, however, that the destruction of the islands, in rivers, is often attended with great loss of life. Thus when the principal river in Virginia rose in 1771, to the height of 25 feet above its ordinary level, it swept entirely away Elk Island, on which were 700 head of quadrupeds, — horses, oxen, sheep, and hogs, — and nearly 100 houses.‡

The reader will gather, from what was before said respecting the deposition of sediment by aqueous causes, that the greater number of the remains of quadrupeds drifted away by rivers must be intercepted by lakes before they reach the sea, or buried in freshwater formations near the mouths of rivers. If they are carried still farther, the probabilities are increased of their rising to the surface in a

* This account I had from Mr. Baumhauer, Director-General of Finances in Java.

† Tracts on India, p. 397.

‡ Scots Mag., vol. xxxiii.

state of putrefaction, and, in that case, of being there devoured by aquatic beasts of prey, or of subsiding into some spots whither no sediment is conveyed, and, consequently, where every vestige of them will, in the course of time, disappear.

Mammalian remains in marine strata.—As the bones of mammalia are often so abundantly preserved in peat, and such lakes as have just been described, the encroachments of the sea upon a coast must sometimes throw down the imbedded skeletons, so that they may be carried away by tides and currents, and entombed in submarine formations. Some of the smaller quadrupeds, also, which burrow in the ground, as well as reptiles and every species of plant, are liable to be cast down into the waves by this cause, which must not be overlooked, although, perhaps, of comparatively small importance amongst the numerous agents whereby terrestrial organic remains are included in submarine strata.

During the great earthquake of Conception in 1835, some cattle, which were standing on the steep sides of the island of Quiriquina, were rolled by the shock into the sea, while on a low island at the head of the Bay of Conception seventy animals were washed off by a great wave and drowned.*

* Darwin's Journal, p. 372, 2nd ed. 1845, p. 304.

CHAPTER XLVII.

IMBEDDING OF THE REMAINS OF MAN AND HIS WORKS IN SUBAQUEOUS STRATA.

DRIFTING OF HUMAN BODIES TO THE SEA BY RIVER INUNDATIONS—HOW HUMAN CORPSES MAY BE PRESERVED IN RECENT DEPOSITS—FOSSIL SKELETONS OF MEN—NUMBER OF WRECKED VESSELS—FOSSIL CANOES, SHIPS, AND WORKS OF ART—CHEMICAL CHANGES WHICH METALLIC ARTICLES HAVE UNDERGONE AFTER LONG SUBMERGENCE—IMBEDDING OF CITIES AND FORESTS IN SUBAQUEOUS STRATA BY SUBSIDENCE—EARTHQUAKE OF CUTCH IN 1819—BURIED TEMPLES OF CASHMERE—BERKELEY'S ARGUMENTS FOR THE RECENT DATE OF THE CREATION OF MAN—MONUMENTS OF PRE-HISTORIC MAN DISCOVERED IN POST-TERTIARY STRATA.

I SHALL now proceed to enquire in what manner the mortal remains of man and the works of his hands may be permanently preserved in subaqueous strata. Of the many hundred million human beings which perish in the course of every century on the land, every vestige is usually destroyed in a few thousand years; but of the smaller number that perish in the waters, a certain proportion must be entombed under circumstances that may enable parts of them to endure throughout entire geological epochs.

The bodies of men, together with those of the inferior animals, are occasionally washed down during river inundations into seas and lakes. Belzoni witnessed a flood on the Nile in September, 1818, where, although the river rose only three feet and a half above its ordinary level, several villages, with some hundreds of men, women, and children, were swept away.* It was before mentioned that a rise of six feet of water in the Ganges, in 1763, was attended with a much greater loss of life. (See above, Vol. I. p. 472.)

In the year 1771, when the inundations in the north of

* Narrative of Discovery in Egypt, &c. London, 1820.

England appear to have equalled the floods of Morayshire in 1829, a great number of houses and their inhabitants were swept away by the rivers Tyne, Can, Wear, Tees, and Greta; and no less than twenty-one bridges were destroyed in the courses of these rivers. At the village of Bywell the flood tore the dead bodies and coffins out of the churchyard, and bore them away, together with many of the living inhabitants. During the same tempest an immense number of cattle, horses, and sheep were also transported to the sea, while the whole coast was covered with the wreck of ships. Four centuries before (in 1338), the same district had been visited by a similar continuance of heavy rains followed by disastrous floods, and it is not improbable that these catastrophes may recur periodically, though after uncertain intervals. As the population increases, and buildings and bridges are multiplied, we must expect the loss of lives and property to augment.*

Preservation of human bodies in the bed of the sea.—If to the hundreds of human bodies committed to the deep in the way of ordinary burial we add those of individuals lost by shipwrecks, we shall find that, in the course of a single year, a great number of human remains are consigned to the subaqueous regions. I shall hereafter advert to a calculation by which it appears that more than 500 *British* vessels alone, averaging each a burden of about 120 tons, were wrecked, and sunk to the bottom, *annually* between the years 1793 and 1829. Of these the crews for the most part escape, although it sometimes happens that all perish. In one great naval action several thousand individuals sometimes share a watery grave.

Many of these corpses are instantly devoured by predaceous fish, sometimes before they reach the bottom; still more frequently when they rise again to the surface, and float in a state of putrefaction. Many decompose on the floor of the ocean, where no sediment is thrown down upon them; but if they fall upon a reef where corals and shells are becoming agglutinated into a solid rock, or subside where the delta of

* Scots Mag. vol. xxxiii. 1771.

a river is advancing, they may be preserved for an incalculable series of ages.

Often at the distance of a few hundred feet from a coral reef, where wrecks are not unfrequent, there are no soundings at the depth of many hundred fathoms. Canoes, merchant vessels, and ships of war may have sunk and have been enveloped, in such situations, in calcareous sand and breccia, detached by the breakers from the summit of a submarine mountain. Should a volcanic eruption happen to cover such remains with ashes and sand, and a current of lava be afterwards poured over them, the ships and human skeletons might remain uninjured beneath the superincumbent mass, like the houses and works of art in the subterranean cities of Campania. Already many human remains may have been thus preserved beneath formations more than 1,000 feet in thickness; for, in some volcanic archipelagos, a period of thirty or forty centuries might well be supposed sufficient for such an accumulation.

Even on that part of the floor of the ocean to which no accession of drift matter is carried (a part which probably constitutes, at any given period, by far the larger proportion of the whole submarine area), there are circumstances accompanying a wreck which favour the conservation of skeletons. For when the vessel fills suddenly with water, especially in the night, many persons are drowned between decks and in their cabins, so that their bodies are prevented from rising again to the surface. The vessel often strikes upon an uneven bottom and is overturned; in which case the ballast, consisting of sand, shingle, and rock, or the cargo, frequently composed of heavy and durable materials, may be thrown down upon the carcasses. In the case of ships of war, cannon, shot, and other warlike stores, may press down with their weight the timbers of the vessel as they decay, and beneath these and the metallic substances the bones of man may be preserved.

Power of human remains to resist decay.—There can be no doubt that human remains are as capable of resisting decay as are the harder parts of the inferior animals; and I have already cited the remark of Cuvier, that 'in ancient fields of

battle the bones of men have suffered as little decomposition as those of horses which were buried in the same grave.' (See above, Vol. I. p. 165.) In the delta of the Ganges bones of men have been found in digging a well at the depth of 90 feet;* but as that river frequently shifts its course and fills up its ancient channels, we are not called upon to suppose that these bodies are of extremely high antiquity, or that they were buried when that part of the surrounding delta where they occur was first gained from the sea.

Several skeletons of men, more or less mutilated, have been found in the West Indies, on the north-west coast of the main land of Guadaloupe, in a kind of rock which is known to be forming daily, and which consists of minute fragments of shells and corals, incrusted with a calcareous cement resembling travertin, by which also the different grains are bound together. The lens shows that some of the fragments of coral composing this stone still retain the same red colour which is seen in the reefs of living coral which surround the island. The shells belong to species of the neighbouring sea intermixed with some terrestrial kinds which now live on the island, and among them is the *Bulimus Guadaloupensis* of Férussac. The human skeletons still retain some of their animal matter, and all their phosphate of lime. One of them, of which the head is wanting, may now be seen in the British Museum, and another in the Royal Cabinet at Paris. According to M. König, the rock in which the former is enclosed is harder under the mason's saw and chisel than statuary marble. It is described as forming a kind of glacis, probably an indurated beach, which slants from the steep cliffs of the island to the sea, and is nearly all submerged at high tide.

Number of wrecked vessels.—When we reflect on the number of curious monuments consigned to the bed of the ocean in the course of every naval war from the earliest times, our conceptions are greatly raised respecting the multiplicity of lasting memorials which man is leaving of his labours. During our last great struggle with France, thirty-two of

* Von Hoff, vol. i. p. 379.

our ships of the line went to the bottom in the space of twenty-two years, besides seven 50-gun ships, eighty-six frigates, and a multitude of smaller vessels. The navies of the other European powers, France, Holland, Spain, and Denmark, were almost annihilated during the same period, so that the aggregate of their losses must have many times exceeded that of Great Britain. In every one of these ships were batteries of cannon constructed of iron or brass, whereof a great number had the dates and places of their manufacture inscribed upon them in letters cast in metal. In each there were coins of copper, silver, and often many of gold, capable of serving as valuable historical monuments; in each were an infinite variety of instruments of the arts of war and peace; many formed of materials, such as glass and earthenware, capable of lasting for indefinite ages when once removed from the mechanical action of the waves, and buried under a mass of matter which may exclude the corroding action of sea-water. The quantity, moreover, of timber which is conveyed from the land to the bed of the sea by the sinking of ships of a large size is enormous; for it is computed that 2,000 tons of wood are required for the building of one 74-gun ship; and reckoning fifty oaks of 100 years' growth to the acre, it would require forty acres of oak forest to build one of these vessels.*

But it would be an error to imagine that the fury of war is more conducive than the peaceful spirit of commercial enterprise to the accumulation of wrecked vessels in the bed of the sea. From an examination of Lloyd's lists, from the year 1793 to the commencement of 1829, the late Admiral Smyth ascertained that the number of *British vessels* alone lost during that period amounted on an average to no less than one and a half *daily*; an extent of loss which would hardly have been anticipated, although we learn from Moreau's tables that the number of merchant vessels employed at that time, in the navigation of England and Scotland, amounted to about 20,000, having one with another a mean burden of 120 tons.† According to Lloyd's list for the

* Quart. Journ. of Agricult., No. ix. p. 433.

† Cæsar Moreau's Tables of the Navigation of Great Britain.

years 1829, 1830, and 1831, no less than 1,953 vessels were lost in those three years, their average tonnage being about 150 tons, or in all nearly 300,000 tons, being at the enormous rate of 100,000 tons annually of the merchant vessels of one nation only.

Out of 551 ships of the royal navy lost to the country during the period above mentioned, only 160 were taken or destroyed by the enemy, the rest having either stranded or foundered, or having been burnt by accident: a striking proof that the dangers of our naval warfare, however great, may be far exceeded by the storm, the shoal, the lee-shore, and all the other perils of the deep.*

In the wreck register for 1866, published by the Board of Trade, the number of shipwrecks and other casualties at sea is stated at no less than 1,860 on the coast of the United Kingdom and in the adjacent seas, and the number of persons drowned as 896, showing how greatly the loss increases from increasing activity in commerce.

Buried ships, canoes, and works of art.—When a vessel is stranded in shallow water, it usually becomes the nucleus of a sandbank, as has been exemplified in several of our harbours, and this circumstance tends greatly to its preservation. Between the years 1780 and 1790 a vessel from Purbeck, laden with 300 tons of stone, struck on a shoal off the entrance of Poole Harbour and foundered; the crew were saved, but the vessel and cargo remain to this day at the bottom. Since that period the shoal at the entrance of the harbour has so extended itself in a westerly direction towards Peveril Point in Purbeck, that the navigable channel is thrown a mile nearer that point.† The cause is obvious: the tidal current deposits the sediment with which it is charged around any object which checks its velocity. Matter also drifted along the bottom is arrested by any obstacle, and accumulates round it, just as the African sand-winds, before described, raise a small hillock over the carcass of every dead camel exposed on the surface of the desert.

I before alluded to an ancient Dutch vessel, discovered in

* I give these results on the authority of the late Admiral Smyth, R.N.

† This account I received from Bishop Harris.

the deserted channel of the river Rother, in Sussex, of which the oak wood was much blackened, but its texture unchanged. (See above, Vol. I. p. 533.) The interior was filled with fluviatile silt, as was also the case in regard to a vessel discovered in a former bed of the Mersey, and another disinterred where the St. Katherine Docks are excavated in the alluvial plain of the Thames. In like manner many ships have been found preserved entire in modern strata, formed by the silting up of estuaries along the southern shores of the Baltic, especially in Pomerania. Between Bromberg and Nakel, for example, a vessel and two anchors in a very perfect state were dug up far from the sea.*

Several vessels have been lately detected half buried in the delta of the Indus, in the numerous deserted branches of that river, far from where the stream now flows. One of these, found near Vikkar in Sinde, was 400 tons in burden, old-fashioned, and pierced for fourteen guns, and in a region where it had been matter of dispute whether the Indus had ever been navigable by large vessels.†

At the mouth of a river in Nova Scotia, a schooner of 32 tons, laden with live stock, was lying with her side to the tide, when the bore, or tidal wave, which rises there about 10 feet in perpendicular height, rushed into the estuary, and overturned the vessel, so that it instantly disappeared. After the tide had ebbed, the schooner was so totally buried in the sand, that the taffrel or upper rail over the stern was alone visible.‡ We are informed by Leigh that, on draining Martin Mere, a lake eighteen miles in circumference, in Lancashire, a bed of marl was laid dry, wherein no fewer than eight canoes were found imbedded. In figure and dimensions they were not unlike those now used in America. In a morass about nine miles distant from this mere a whetstone and an axe of mixed metal were dug up.§ In Ayrshire, also, three canoes were found in Loch Doon early in the present century; and during the year 1831 four others, each

* Von Hoff, vol. i. p. 368.

† Lieut. Carless, Geograph. Journ. vol. viii. p. 338.

‡ Silliman's Geol. Lectures, p. 78, who cites Penn.

§ Leigh's Lancashire, p. 17. A.D. 1700.

hewn out of a single oak tree. They were 23 feet in length, 2½ in depth, and nearly 4 feet in breadth at the stern. In the mud which filled one of them were found a war-club of oak and a stone battle-axe. A canoe of oak was also found in 1820, in peat overlying the shell-marl of the Loch of Kinnordy in Forfarshire.*

Manner in which ships may be preserved in a deep sea.—It is extremely possible that the submerged woodwork of ships which have sunk where the sea is two or three miles deep has undergone greater chemical changes in an equal space of time than in the cases above mentioned; for the experiments of Scoresby show that wood may at certain depths be impregnated in a single hour with salt water, so that its specific gravity is entirely altered. (See above, p. 532.) It may often happen that springs charged with carbonate of lime, silex, and other mineral ingredients, may issue at great depths, in which case every pore of the vegetable tissue may be injected with the lapidifying liquid, whether calcareous or siliceous, before the smallest decay commences. The conversion, also, of wood into lignite is probably more rapid under enormous pressure. But the change of the timber into lignite or coal would not prevent the original form of a ship from being distinguished; for as we find, in strata of the carboniferous era, the bark of the hollow reed-like trees converted into coal, and the central cavity filled with sandstone, so might we trace the outline of a ship in coal; while in the indurated mud, sandstone, or limestone, filling the interior, we might discover instruments of human art, ballast consisting of rocks foreign to the rest of the stratum, and other contents of the ship.

Submerged metallic substances.—Many of the metallic substances which fall into the waters probably lose, in the course of ages, the forms artificially imparted to them; but under certain circumstances these may be preserved for indefinite periods. The cannon enclosed in a calcareous rock, drawn up from the delta of the Rhone, which is now in the museum at Montpellier, might probably have endured as long as the

* Geol. Trans., second series, vol. ii. p. 87. For buried canoes near Glasgow see 'Antiquity of Man,' p. 48.

calcareous matrix; but even if the metallic matter had been removed, and had entered into new combinations, still a mould of its original shape would have been left, corresponding to those impressions of shells which we see in rocks, from which all the carbonate of lime has been subtracted. About the year 1776, says Mr. King, some fishermen, sweeping for anchors in the Gull-stream (a part of the sea near the Downs), drew up a very curious old swivel gun, nearly eight feet in length. The barrel, which was about five feet long, was of brass; but the handle by which it was traversed was about three feet in length, and the swivel and pivot on which it turned were of iron. Around these latter were formed incrustations of sand converted into a kind of stone, of exceedingly strong texture and firmness; whereas round the barrel of the gun, except where it was near adjoining to the iron, there were no such incrustations, the greater part of it being clean, and in good condition, just as if it had still continued in use. In the incrusting stone, adhering to it on the outside, were a number of shells and corallines, 'just as they are often found in a fossil state.' These were all so strongly attached, that it required as much force to separate them from the matrix 'as to break a fragment off any hard rock.'*

In the year 1745, continues the same writer, the Fox man-of-war was stranded on the coast of East Lothian, and went to pieces. About thirty-five years afterwards a violent storm laid bare a part of the wreck, and threw up near the place several masses, 'consisting of iron, ropes, and balls,' covered over with ochreous sand, concreted and hardened into a kind of stone. The substance of the rope was very little altered. The consolidated sand retained perfect impressions of parts of an iron ring, 'just as impressions of extraneous fossil bodies are found in various kinds of strata.' †

After a storm in the year 1824, which occasioned a considerable shifting of the sands near St. Andrew's, in Scotland, a gun-barrel of ancient construction was found, which is conjectured to have belonged to one of the wrecked vessels of

* Phil. Trans., 1779. † Ibid., vol. lxix. 1779.

the Spanish Armada. It is now in the museum of the Antiquarian Society of Scotland, and is incrusted over by a thin coating of sand, the grains of which are cemented by brown ferruginous matter. Attached to this coating are fragments of various shells, as of the common Cardium, Mya, &c.

Many other examples are recorded of iron instruments taken up from the bed of the sea near the British coast, incased by a thick coating of conglomerate, consisting of pebbles and sand, cemented by oxide of iron.

Dr. Davy describes a bronze helmet, of the antique Grecian form, taken up in 1825, from a shallow part of the sea, between the citadel of Corfu and the village of Castrades. Both the interior and exterior of the helmet were partially incrusted with shells and a deposit of carbonate of lime. The surface generally, both under the incrustation and where freed from it, was of a variegated colour, mottled with spots of green, dirty white, and red. On minute inspection with a lens, the green and red patches proved to consist of crystals of the red oxide and carbonate of copper, and the dirty white chiefly of oxide of tin.

The mineralising process, says Dr. Davy, which has produced these new combinations, has, in general, penetrated very little into the substance of the helmet. The incrustation and rust removed, the metal is found bright beneath; in some places considerably corroded, in others very slightly. It proves, on analysis, to be copper alloyed with 18·5 per cent. of tin. Its colour is that of our common brass, and it possesses a considerable degree of flexibility.

'It is a curious question,' he adds, 'how the crystals were formed in the helmet, and on the adhering calcareous deposit. There being no reason to suppose deposition from solution, are we not under the necessity of inferring, that the mineralising process depends on a small motion and separation of the particles of the original compound? This motion may have been due to the operation of electro-chemical powers which may have separated the different metals of the alloy.' *

* Phil. Trans., 1826, part ii. p. 55.

Millions of silver dollars and other coins have been sometimes submerged in a single ship, and on these, when they happen to be enveloped in a matrix capable of protecting them from chemical changes, much information of historical interest will remain inscribed, and endure for periods as indefinite as have the delicate markings of zoophytes or lapidified plants in some of the ancient paleozoic rocks. In almost every large ship, moreover, there are some precious stones set in seals, and other articles of use and ornament composed of the hardest substances in nature, on which letters and various images are carved—engravings which they may retain when included in subaqueous strata, as long as a crystal preserves its natural form.

It was, therefore, a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle

> ——as rich with praise
> As is the ooze and bottom of the deep
> With sunken wreck and sumless treasuries;

for it is probable that a greater number of monuments of the skill and industry of man will, in the course of ages, be collected together in the bed of the ocean, than will exist at any one time on the surface of the continents.

CITIES AND FORESTS SUBMERGED BY THE SUBSIDENCE OF LAND.

Examples of the sinking down of buildings, and portions of towns near the shore, to various depths beneath the level of the sea during subterranean movements, were enumerated in the first volume, Chapter XXIV. The events alluded to were comprised within a brief portion of the historical period, and confined to a small number of the regions of active volcanos. Yet these authentic facts, relating merely to the last century and a half, gave indications of considerable changes in the physical geography of the globe, and we are not to suppose that these were the only spots throughout the surrounding land and sea which suffered similar depressions.

If, during the short period since South America has been colonised by Europeans, we have proof of alterations of level at the three principal ports on the western shores, Callao, Valparaiso, and Conception,* we cannot for a moment suspect that these cities, so distant from each other, have been selected as the peculiar points where the desolating power of the earthquake has expended its chief fury. On considering how small is the area occupied by the seaports of this disturbed region—points where alone each slight change of the relative level of the sea and land can be recognised,—and reflecting on the proofs in our possession of the local revolutions that have happened on the site of each port, within the last century and a half,—our conceptions must be greatly exalted respecting the magnitude of the alterations which the country between the Andes and the sea may have undergone, even in the course of the last six thousand years.

Cutch earthquake.—The manner in which a large extent of surface may be submerged, so that the terrestrial plants and animals may be imbedded in subaqueous strata, cannot be better illustrated than by the earthquake of Cutch, in 1819, before alluded to (p. 97). It is stated that for some years after that earthquake, the withered tamarisks and other shrubs protruded their tops above the waves, in parts of the lagoon formed by subsidence, on the site of the village of Sindree and its environs; but, after the flood of 1826, they were seen no longer. Every geologist will at once perceive that forests sunk by such subterranean movements may become imbedded in subaqueous deposits, both fluviatile and marine, and the trees may still remain erect, or sometimes the roots and part of the trunks may continue in their original position, while the current may have broken off, or levelled with the ground, their upper stems and branches.

Buildings how preserved under water.—Some of the buildings which have at different times subsided beneath the level of the sea have been immediately covered up to a certain extent with strata of volcanic matter showered down upon them. Such was the case at Tomboro in Sumbawa, in the present century, and on the site of the Temple of Serapis, in the

* See above, pp. 90, 94, 154, 156.

environs of Puzzuoli, probably about the 12th century. The entrance of a river charged with sediment in the vicinity may still more frequently occasion the rapid envelopment of buildings in regularly stratified formations. But, if no foreign matter be introduced, the buildings, when once removed to a depth where the action of the waves is insensible, and where no great current happens to flow, may last for indefinite periods, and be as durable as the floor of the ocean itself, which may often be composed of the very same materials. There is no reason to doubt the tradition mentioned by the classic writers, that the submerged Grecian towns of Bura and Helice were seen under water; and ruins of old submerged towns are mentioned by Captain Spratt as being visible in the sea off the eastern extremity of Crete or Candia. It has been already mentioned that different eye-witnesses have observed the houses of Port Royal, at the bottom of the sea, at intervals of 88, 101, and 143 years after the convulsion of 1692 (p. 160).

Buried temples of Cashmere. — The celebrated valley of Cashmere (or Kashmir) in India, situated at the southern foot of the Himalaya range, is about 60 miles in length, and 20 in breadth, surrounded by mountains which rise abruptly from the plain to the height of about 5,000 feet. In the cliffs of the river Jelam and its tributaries, which traverse this beautiful valley, strata consisting of fine clay, sand, soft sandstone, pebbles, and conglomerate are exposed to view. They contain freshwater shells, of the genera Lymneus, Paludina, and Cyrena, with landshells, all of recent species, and are precisely such deposits as would be formed if the whole valley were now converted into a great lake, and if the numerous rivers and torrents descending from the surrounding mountains were allowed sufficient time to fill up the lake-basin with fine sediment and gravel. Fragments of pottery met with at the depth of 40 and 50 feet in this lacustrine formation show that the upper part of it at least has accumulated within the human epoch.

Dr. Thomas Thomson, who visited Cashmere in 1848, observes that several of the lakes which still exist in the great valley, such as that near the town of Cashmere, five miles in

diameter, and some others, are deeper than the adjoining river-channels, and may have been formed by subsidence during the numerous earthquakes which have convulsed that region in the course of the last 2,000 years. It is also probable that the freshwater strata seen to extend far and wide over the whole of Cashmere originated not in one continuous sheet of water once occupying the entire valley, but in many lakes of limited area, formed and filled in succession. Among other proofs of such lake-basins of moderate dimensions having once existed and having been converted into land at different periods, Dr. Thomson mentions that the ruins of Avantipura, not far from the modern village of that name, stand on an older freshwater deposit at the base of the mountains, and terminate abruptly towards the plain in a straight line, such as admits of no other explanation than by supposing that the advance of the town in that direction was arrested by a lake, now drained or represented only by a marsh. In that neighbourhood, as very generally throughout Cashmere, the rivers run in channels or alluvial flats, bounded by cliffs of lacustrine strata, horizontally stratified, and these strata form low table-lands from 20 to 50 feet high between the different watercourses. On a table-land of this kind near Avantipura, portions of two buried temples are seen, which have been partially explored by Major Cunningham, who, in 1847, discovered that in one of the buildings a magnificent colonnade of seventy-four pillars is preserved underground. He exposed to view three of the pillars in a cavity still open. All the architectural decorations below the level of the soil are as perfect and fresh-looking as when first executed. The spacious quadrangle must have been silted up gradually at first, for some unsightly alterations, not in accordance with the general plan and style of architecture, were detected, evidently of subsequent date, and such as could only have been required when the water and sediment had already gained a certain height in the interior of the temple.

This edifice is supposed to have been erected about the year 850 of our era, and was certainly submerged before the year 1416, when the Mahomedan king, Sikandar, called Butshikan or the idol-breaker, destroyed all the images of Hindoo

temples in Cashmere. Ferishta, the historian, particularly alludes to Sikandar having demolished every Cashmerian temple save one, dedicated to Mahadéva, which escaped 'in consequence of its foundations being below the neighbouring water.' The unharmed condition of the human-headed birds and other images in the buried edifice near Avantipura leaves no doubt that they escaped the fury of the iconoclast by being under water, and perhaps silted up before the date of his conquest.*

MODERN ORIGIN OF MAN AS INFERRED FROM GEOLOGICAL EVIDENCE.

Bishop Berkeley on the recent date of the creation of man.—Bishop Berkeley, in a memorable passage written more than a century ago, inferred, on grounds which may be termed strictly geological, the recent date of the creation of man. 'To anyone,' says he, 'who considers that on digging into the earth, such quantities of shells, and in some places, bones and horns of animals, are found sound and entire, after having lain there in all probability some thousands of years, it should seem probable that guns, medals, and implements in metal or stone might have lasted entire, buried under ground forty or fifty thousand years, if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglios, cameos, statues, basso-relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence of those mighty empires, those successions of monarchs, heroes, and demi-gods, for so many thousand years? Let us look forward and suppose ten or twenty thousand years to come, during which time we will suppose that plagues, famine, wars, and *earthquakes* shall have made great havoc in the world, is it not highly probable that at the end of such a period, pillars, vases, and statues now in being of granite, or

* Thomson's Western Himalaya and Thibet, p. 292. London, 1852. Cunningham, vol. xvii. Journ. Asiat. Soc. Bengal, pp. 241, 277.

porphyry, or jasper (stones of such hardness as we know them to have lasted 2,000 years above ground, without any considerable alteration), would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls and the foundations of buildings show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times?' *

We may with confidence anticipate, like Berkeley, that if the duration of the planet is indefinitely protracted, many edifices and implements of human workmanship and the skeletons of men will be entombed in freshwater, marine, and volcanic strata, and will continue to exist even when a great part of the present mountains, continents, and seas shall have disappeared. The earth's crust must be remodelled more than once before all the memorials of man which are continually becoming entombed in the rocks now forming will be destroyed. *One* complete revolution will be inadequate to efface every monument of our existence; for many works of art might enter again and again into the formations of successive eras, and escape obliteration even though the very rocks in which they had been for ages imbedded were destroyed, just as pebbles included in the conglomerates of one epoch often contain the organised remains of beings which flourished during a prior era.

Yet it is no less true, as a late distinguished philosopher has declared, 'that none of the works of a mortal being can be eternal.' They are in the first place wrested from the hands of man and lost, so far as regards their subserviency to his use, by the instrumentality of those very causes which place them in situations where they are enabled to endure for indefinite periods. And even when they have been included in rocky strata, when they have been made to enter as it were into the solid framework of the globe itself, they must nevertheless eventually perish; for every year some portion of the earth's crust is shattered by earthquakes, or melted by volcanic fire, or ground to dust by the moving waters on the surface. 'The river of Lethe,' as Bacon

* Alciphron, or the Minute Philosopher, vol. ii. pp. 84, 85. 1732.

eloquently remarks, runneth as well above ground as below.' *

Monuments of pre-historic man in Europe.—The reader will see from what was said in the forty-third chapter, that although we might expect man to become cosmopolitan as soon as he had acquired such intellectual superiority as belongs even to the lowest of the human races now inhabiting the globe, yet so long as he was slightly inferior to these races, he may have continued for an indefinite time restricted to one limited area, like the living species of anthropomorphous mammalia. Even if he existed as a rational being before the close of the Pliocene Period, we have no right to assume in the present state of science that we should have obtained geological evidence of his existence. When treating of the changes of climate in the first volume, I gave some account (p. 174) of the results of the joint investigations of the geologist and archæologist in regard to the remains of pre-historic man. It will there be seen that all these remains belong to the latter part of that modern period in geology which I have called Post-tertiary, when all the shells, marine and freshwater, were already of the same species as those now living.

The age of Iron was preceded in Europe by that of Bronze, when tools of that mixed metal were in use. These bronze weapons prevailed in Switzerland and Gaul long before the Roman invasion of those countries. Implements of the same mixture of copper and tin occur in many of the Swiss lake-villages and in the peat-mosses of Great Britain, Ireland, and Scandinavia. But coins are entirely absent, and no proofs of the art of writing or of letters having been invented have yet been brought to light. Some of the pottery of the Bronze age is said to show marks of the potter's wheel, but the greater part of it was made by hand. Professor Nilsson long ago observed that the handles of the swords as well as the bracelets of the Bronze age indicate that the size of the race which used them was smaller than that of the present inhabitants of Northern Europe. Many animals had been domes-

* Essay on the Vicissitude of Things.

ticated by man in this period, as is shown by the bones preserved in certain Swiss lake-dwellings; several cereals also and fruits were cultivated. Gold, amber, and glass were in use for ornamental purposes, but there is no evidence that silver, zinc, and lead were known. In the Swiss lake-villages of the antecedent Stone period called Neolithic, as being newer than a still older age of stone, men were evidently ignorant of the art of metallurgy. Polished axes commonly called celts, chisels, and other tools, were so abundant in Northern and Western Europe that the Dublin Museum contains more than 2,000 of them, that of Copenhagen more than 10,000, and that of Stockholm not fewer than 15,000.*

The Danish shell-mounds or kitchen-middens, as well as many of the Swiss lake-dwellings, and a large part of the European peat, belong to this Neolithic period, but none of the polished implements of this age occur in the river-drift gravel-beds, nor in association with extinct mammalia. Hand-made pottery was in use; the ox, sheep, goat, pig and dog were already domesticated, agriculture had commenced, and flax was cultivated and woven into tissues.

Next in our retrospective survey we come to the monuments of what M. Lartet has called the Rein-deer period, when that animal abounded in the South of France.

To this era belong the caves of the Dordogne in central France, in which MM. Lartet, Christy, and others have obtained thousands of implements made out of stone, bone, and horn without a trace of any associated pottery, still less of metallic tools, or polished stone implements. M. Lartet found in one cave of this period at La Madeleine a fragment of mammoth tusk on which was rudely carved a representation of the animal itself; a fact which seems to prove that this species coexisted with these cave-men. Traces also of the musk-ox and cave-lion have been met with in the same caves, but some doubts are still entertained whether these quadrupeds were contemporary with the men of the Rein-deer period. This period may be considered as intermediate

* Sir J. Lubbock. Introduction to Translation of Nilsson's 'Primitive Inhabitants of Scandinavia,' p. xxiv.

between the Neolithic and Palæolithic ages, but it has been classed provisionally by Sir J. Lubbock as Palæolithic. The climate then prevailing in the south of Europe was evidently much colder than it is now, but the state of physical geography has not since undergone any material alteration.

Lastly we arrive at the still older monuments of the Palæolithic period properly so called, which consist chiefly of unpolished stone implements buried in ancient river-gravels and in the mud and stalagmite of caves. Both the gravel and the caves are now so situated in their relation to the present drainage and geography of the countries where they occur as to imply a great lapse of intervening time during which the erosive power of rivers has been active in deepening the valleys. The implements of this age in Western Europe are chiefly composed of chalk-flint—more rarely of chert from the greensand. Besides being unpolished they differ in shape from those of the Neolithic age.* They are associated with remains of the mammoth, the woolly-haired rhinoceros, the hippopotamus, the musk-ox, and many other quadrupeds of extinct and living species. No pottery has been found strictly referable to this era, and there is an entire absence of metallic weapons, as in the later Bronze period of coins.

The beds of gravel often called drift, which contain antiquities of this age, may be said to have been deposited by the existing rivers, when these ran in the same direction as at present, and drained the same areas, but before the valleys had been scooped out to their present depth. The height above the present alluvial plains at which the old drift occurs is often no more than 20 or 30 feet, but sometimes 100 or even 200 feet. Flint flakes having a fine cutting edge, evidently chipped off by the hand of man, are met with not only in the old drift, but in formations of the Neolithic and Bronze ages, for they afford the finest cutting edge that was obtainable before the invention of steel. In the caves of this early Stone period implements of the same antique type, with fossil skeletons of man, have been detected, agreeing, as before hinted,

* See Lyell's 'Antiquity of Man,' pp. 114 and 118, and Lubbock's 'Pre-historic Times.'

(p. 493) in osteological character with some of the existing races of man. It has been estimated that the number of flint implements of the Palæolithic type already found in northern France and southern England, exclusive of flakes, is not less than 3,000.* No similar tools have been met with in Denmark, Sweden, or Norway, where Nilsson, Thomsen, and other antiquaries have collected with so much care the relics of the Stone age. Hence it is supposed that Palæolithic man never penetrated into Scandinavia, which may perhaps have been as much covered with ice and snow as the greater part of Greenland is at present.

Palæolithic implements in the drift of the south of Hampshire. —Flint implements of the normal type of the Palæolithic period have been lately found in the south of Hampshire, not in caves nor in old river-gravels within the limits of existing valleys, but in a tabular mass of drift which caps the Tertiary strata, and which is intersected both by the Solent and by the valleys of all the rivers which flow into that channel of the sea. The position of these implements, to which the archæologists of Salisbury have called our attention within the last four years, attests perhaps in a more striking manner the antiquity of pre-historic man in Europe than any other monument of the earlier Stone age yet discovered. The great bed of gravel resting on Eocene Tertiary strata in which these implements have been found, consists in most places of half-rolled or semi-angular chalk-flints, mixed with rounded pebbles washed out of the Tertiary strata. But this drift, although often continuous over wide areas, is not everywhere present, nor does it always present the same characters. The first flint implements found in it were discovered mid-way between Gosport and Southampton, by Mr. James Brown of Salisbury, in May 1864, included in gravel from 8 to 12 feet thick, capping a cliff which at its greatest height is 35 feet above high-water mark. I have visited this spot, which had previously been seen by Messrs. Prestwich and Evans. The flint-tools exactly resemble those found at Abbeville and Amiens in France, being some of them of the oval, and

* Sir J. Lubbock, Introduction to Nilsson's 'Primitive Inhabitants of Scandinavia,' p. xx.

others of the lanceolate form. Many of them exhibit the same colours and ochreous stain as do the flints in the gravel in which they lay. A fine series of these implements, from the Hampshire cliffs, may now be seen in the Blackmore Museum at Salisbury.

In the gravel capping the cliffs alluded to are blocks of sandstone of various sizes, some of enormous dimensions, more than 20 feet in circumference and from 1 to 2½ feet thick. They have probably not travelled far, being a portion of the wreck of the Eocene strata which have suffered much denudation. Nevertheless to explain how they and the stone implements became enveloped in the débris of chalk-flints, we must have recourse to ice, which may have been frozen on to them in winter, so as to give them buoyancy and enable rivers or the sea to transport them to slight distances from their original site. An extreme climate, causing a vast accumulation of snow during a cold winter, and great annual floods when this snow was suddenly melted in the beginning of the warm season, may best account for the destruction of large masses of chalk in the upland country, and the spreading over the ancient surface of the flinty material originally dispersed in layers through the soft chalk. The occasional occurrence of unrolled chalk-flints in the gravel in places where they must have travelled twelve miles from their nearest source, also implies the aid of ice-action. The transverse valleys now intersecting the region near the coast where the flint tools are found, near Gosport, must have been cut through the Tertiary strata, after the over-lying gravel had been superimposed, for this last forms a flat table-land between the valleys.

On the whole we may infer that not only the valleys of the smaller streams near Gosport, but those of the Test (or Southampton river) and of the stream which enters at Lymington, and those of the rivers Avon and Stour, which reach the Solent at Christchurch, as well as the Bournemouth valley, have all been excavated since Palæolithic man inhabited this region; for not only at various points east of the Southampton estuary, but west of it also on both sides of the opening at Bournemouth, flint tools of the ancient type have been met

with in the gravel capping the cliffs. The gravel from which the flint tool was taken at Bournemouth is about 100 feet above the level of the sea; as I ascertained after examining the spot in 1867.*

The gravel consists in great part of pebbles derived from Tertiary strata; and if it was originally spread out by rivers, the course of the drainage must since have been altered to such an extent that it is not easy to trace any connection between the old watercourses and those of the existing valleys.

I learn from Mr. Evans that Mr. Thomas Codrington discovered in 1868 an oval flint implement in gravel at the top of the Foreland cliff on the most eastern point of the Isle of Wight five miles south-east of Ryde. It is of the true Palæolithic type, and the gravel in which it is imbedded at the height of about 80 feet above the level of the sea, may, as Mr. Evans suggests, have once extended to the cliffs near Gosport; in which case we should have to infer that the channel called the Solent had not yet been scooped out when this region was inhabited by Palæolithic man. The gravel found at Freshwater at the west end of the Isle of Wight, in which the remains of the mammoth have been detected, is probably of the same date.

If we ascend the Avon from Christchurch to Salisbury about 30 miles to the north, we find in gravels at various heights above the river, and in old fluviatile alluvium, flint tools of the same Palæolithic type. One of these was taken out by Dr. Blackmore from beneath the remains of a mammoth, at Fisherton, near Salisbury. The remains of no less than 21 species of mammalia have also been detected at the same place, the greatest number, perhaps, obtained in any one spot in Great Britain. The associated land and freshwater shells belong to 31 species, and are all still living in England, although the quadrupeds imply a colder climate. Among these are the mammoth and woolly-haired rhinoceros, the

* Mr. Alfred Stevens first dug out a hatchet (April, 1866) from this gravel at the top of the sea-cliff east of the Bournemouth opening. Dr. Blackmore soon afterwards obtained two other similar implements from gravel west of the Bournemouth valley.

rein-deer, and Norwegian lemming, the Greenland lemming, and another species of the same family, the Spermophilus, allied to the marmot. Of this last 13 individuals have been found, some of the skeletons being perfect, and lying, as remarked by Dr. Blackmore, in the curved attitude of hibernation, as may now be seen in the Blackmore Museum. Besides the bones of quadrupeds, the femur and coracoid bones of the wild goose (*Anser palustris*) have been met with, and some egg-shells corresponding in size with the eggs of the wild goose and wild duck. These shells are in part covered with superficial incrustations. As the wild goose now resorts to arctic regions in the breeding season, the occurrence of its eggs at Fisherton seems to imply a cold climate such as would have suited the lemming and marmot.*

To conclude, there are three independent classes of evidence, which in this part of Hampshire point distinctly to the vast antiquity of Palæolithic man. First, the great denudation of the Chalk and Tertiary strata, and the important changes in the shape and depth of the valleys and the contour of the sea-coast which have since occurred in Hampshire; secondly, a marked change in the fauna, by the dying out of so many conspicuous species of quadrupeds; and thirdly, the change of climate from a colder to a warmer temperature, implied by the former presence of northern animals, and by the ice-borne erratics of the drift.

Age of pottery buried in upraised marine strata in Sardinia.—I have elsewhere called attention† to a marine formation described by Count Albert de la Marmora as occurring at Cagliari, on the southern coast of the island of Sardinia, at the height of more than 300 feet above the level of the Mediterranean. In this deposit some rude fragments of pottery were found together with a flattened ball of baked earthenware, with a hole through the axis, supposed to have been used for weighting fishing-nets. These works of art were associated with marine shells all of living species, the

* Evans, Geol. Quart. Journ., p. 193, Aug. 1864.
† See 'Antiquity of Man,' p. 177.

oysters and mussels having both valves united together. I know of no other instance in Europe of a sea-bottom of the human period having been lifted up 300 feet above its former level; but in countries like Sardinia, where the latest volcanic cones are of Newer Pliocene, if not of Post-Pliocene date, such an upheaval may not imply a greater antiquity than may belong to Neolithic times.

CHAPTER XLVIII.

IMBEDDING OF AQUATIC SPECIES IN SUBAQUEOUS STRATA.

INHUMATION OF FRESHWATER PLANTS AND ANIMALS—SHELL-MARL—FOSSILISED SEED-VESSELS AND STEMS OF CHARA—RECENT DEPOSITS IN AMERICAN LAKES—FRESHWATER SPECIES DRIFTED INTO SEAS AND ESTUARIES—LEWES LEVELS—ALTERNATIONS OF MARINE AND FRESHWATER STRATA, HOW CAUSED—IMBEDDING OF MARINE PLANTS AND ANIMALS—CETACEA STRANDED ON OUR SHORES—LITTORAL AND ESTUARY TESTACEA SWEPT INTO THE DEEP SEA—BURROWING SHELLS—LIVING TESTACEA FOUND AT CONSIDERABLE DEPTHS—BLENDING OF ORGANIC REMAINS OF DIFFERENT AGES.

HAVING treated of the imbedding of terrestrial plants and animals, and of human remains, in deposits now forming beneath the waters, I come next to consider in what manner *aquatic* species may be entombed in strata formed in their own element.

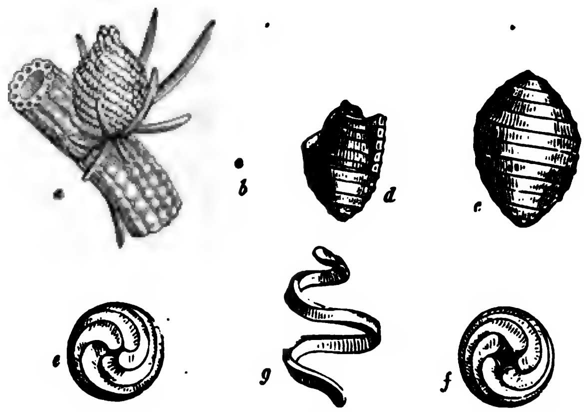
Freshwater plants and animals.—The remains of species belonging to those genera of the animal and vegetable kingdoms which are more or less exclusively confined to fresh water are for the most part preserved in the beds of lakes or estuaries, but they are oftentimes swept down by rivers into the sea, and there intermingled with the exuviæ of marine races. The phenomena attending their inhumation in lacustrine deposits are sometimes revealed to our observation by the drainage of small lakes, such as are those in Scotland, which have been laid dry for the sake of obtaining shell-marl for agricultural uses.

In these modern formations, as seen in Forfarshire, two or three beds of calcareous marl are sometimes observed separated from each other by layers of drift peat, sand, or fissile clay. The marl often consists almost entirely of an aggregate of shells of the genera Limnea, Planorbis, Valvata, and Cyclas, of species now existing in Scotland. A considerable proportion of the Testacea appear to have died very young, and

few of the shells are of a size which indicates their having attained a state of maturity. The shells are sometimes entirely decomposed, forming a pulverulent marl; sometimes in a state of good preservation. They are frequently intermixed with stems of Charæ and other aquatic vegetables, the whole being matted together and compressed, forming laminæ often as thin as paper.

As the Chara is an aquatic plant which occurs frequently fossil in formations of different eras, and is often of much importance to the geologist in characterising entire groups of strata, I shall describe the manner in which I have found the recent species in a petrified state. They occur in a marl-lake in Forfarshire, enclosed in nodules, and sometimes in a continuous stratum of a kind of travertin.

Fig. 146.



Seed-vessel of *Chara hispida*.

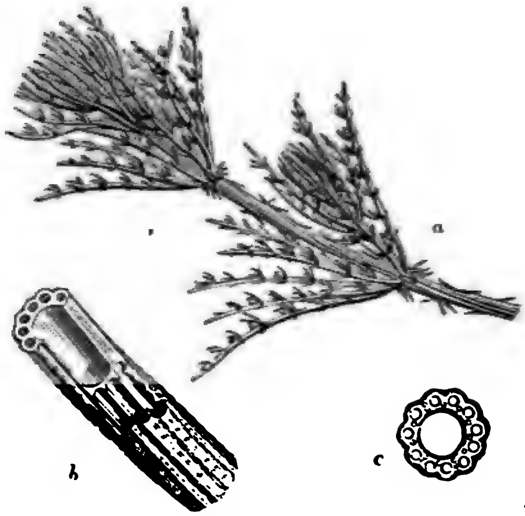
a. Part of the stem with the seed-vessel attached. Magnified.
b. Natural size of the seed-vessel.
c. Integument of the Gyrogonite, or petrified seed-vessel of *Chara hispida*, found in the Scotch marl-lakes. Magnified.
d. Section showing the nut within the integument.
e. Lower end of the integument to which the stem was attached.
f. Upper end of the integument to which the stigmata were attached.
g. One of the spiral valves of *c.*

The seed-vessel of these plants is remarkably tough and hard, and consists of a membranous nut covered by an integument (*d*, fig. 146), both of which are spirally striated or ribbed. The integument is composed of five spiral valves, of

a quadrangular form (*g*). In *Chara hispida*, which abounds in a living state in the lakes of Forfarshire, and which has become fossil in the Bakie Loch, each of the spiral valves of the seed-vessel turns rather more than twice round the circumference, the whole together making between ten and eleven rings. The number of these rings differs greatly in different species, but in the same appears to be very constant.

The stems of Charæ occur fossil in the Scotch marl in great abundance. In some species, as in *Chara hispida*, the plant when living contains so much carbonate of lime in its vegetable organisation, independently of calcareous incrustation, that it effervesces strongly with acids when dry.

Fig. 147.



Stem and branches of *Chara hispida*.

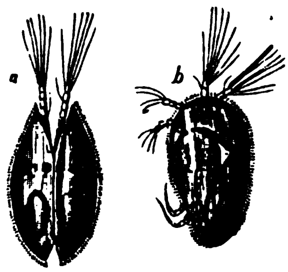
a. Stem and branches of the natural size.
b. Section of the stem magnified.
c. Showing the central tube surrounded by two rings of smaller tubes.

The longitudinal striæ on the stems of *Chara hispida* have a tendency to be spiral, and as appears to be the case with other species of the genus, turn always like the worm of a screw, so that the spiral valves as seen on the outside turn from right to left, while those of the seed-vessel wind round in a contrary direction. A cross section of the stem

exhibits a curious structure, for it is composed of a large tube surrounded by smaller tubes (fig. 147, *b*, *c*), as is seen in some extinct as well as recent species. In the stems of several species, however, there is only a single tube.*

The valves of a small animal called Cypris (*C. ornata*? Lam.) occur completely fossilised, like the stems of Chara, in the Scotch travertin above mentioned. The same Cypris inhabits the lakes and ponds of England, where, together with many other species, it is not uncommon. Although extremely minute, they are visible to the naked eye, and may be observed in great numbers, swimming swiftly through the waters of our stagnant pools and ditches. The antennæ, at the end of which are fine pencils of hair, are the principal organs for swimming, and are moved with great rapidity. The animal

Fig. 148.



Cypris unifasciata, a living species, greatly magnified.

a. Upper part. *b*. Side view of the same.

Fig. 149.

Cypris vidua, a living species, greatly magnified.†

resides within two small valves, not unlike those of a bivalve mollusk, and moults its integuments annually, which the conchiferous mollusk does not. The cast-off shells, resembling thin scales, and occurring in countless myriads in many ancient freshwater marls, impart to them a divisional structure, like that so frequently derived from plates of mica.

The recent strata of lacustrine origin above alluded to are of very small extent, but analogous deposits on the grandest scale are forming in the great Canadian lakes, as in Lakes

* On Freshwater Marl, &c. By C. Lyell, Geol. Trans., vol. ii., second series, p. 73.

† See Desmaret's Crustacea, pl. 55.

Superior and Huron, where beds of sand and clay are seen enclosing shells of existing species. In Lake Superior during the late dredgings (August 1871) the greatest depth ascertained was 1,014 feet, and the temperature of the water everywhere below 40 fathoms (240 feet) was almost constant at 39° F., which is evidently connected with its maximum density. At the surface at the same time it was found to range from 50° to 55° F. In the shallow water the fauna varied with the character of the bottom, while the deep-water fauna, composed of small mollusks and crustaceans, was meagre, and like the temperature seemed to be everywhere very uniform.* The Charæ also play the same part in the subaqueous vegetation of North America as in Europe. I observed along the borders of several freshwater lakes in the State of New York a luxuriant crop of this plant in clear water of moderate depth, rendering the bottom as verdant as a grassy meadow. Here, therefore, we may expect some of the tough seed-vessels to be preserved in mud, just as we detect them fossil in the Eocene strata of Hampshire, or in the neighbourhood of Paris, and in many other countries.

IMBEDDING OF FRESHWATER SPECIES IN ESTUARY AND MARINE DEPOSITS.

We have sometimes an opportunity of examining the deposits which within the historical period have silted up some of our estuaries; and excavations made for wells and other purposes, where the sea has been finally excluded, enable us to observe the state of the organic remains in these tracts. The valley of the Ouse between Newhaven and Lewes is one of several estuaries from which the sea has retired within the last seven or eight centuries; and here, as appears from the researches of Dr. Mantell, strata 30 feet and upwards in thickness have accumulated. At the top, beneath the vegetable soil, is a bed of peat about 5 feet thick, enclosing many trunks of trees. Next below is a stratum of blue clay con-

* Silliman's Journal, Vol. II. p. 373, Nov. 1871.

* Dr. Bigsby, Journ. of Science, &c., No. xxxvii. pp. 262, 263.

taining freshwater shells of about nine species, such as now inhabit the district. Intermixed with these was observed the skeleton of a deer. Lower down, the layers of blue clay contain, with the above-mentioned freshwater shells, several marine species well known on our coast. In the lowest beds, often at the depth of 36 feet, these marine Testacea occur without the slightest intermixture of fluviatile species, and amongst them the skull of a narwal, or sea-unicorn (*Monodon monoceros*), has been detected. Underneath all these deposits is a bed of pipe-clay, derived from the subjacent chalk.*

If we had no historical information respecting the former existence of an inlet of the sea in this valley and of its gradual obliteration, the inspection of the section above described would show, as clearly as a written chronicle, the following sequence of events. First, there was a salt-water estuary peopled for many years by species of marine Testacea identical with those now living, and into which some of the larger Cetacea occasionally entered. Secondly, the inlet grew shallower, and the water became brackish, or alternately salt and fresh, so that the remains of freshwater and marine shells were mingled in the blue argillaceous sediment of its bottom. Thirdly, the shoaling continued until the river-water prevailed, so that it was no longer habitable by marine Testacea, but fitted only for the abode of fluviatile species and aquatic insects. Fourthly, a peaty swamp or morass was formed, where some trees grew, or perhaps were drifted during floods, and where terrestrial quadrupeds were mired. Finally, the soil being flooded by the river only at distant intervals, became a verdant meadow.

It was before stated, that on the sea-coast, in the delta of the Ganges, there are eight great openings, each of which has evidently, at some ancient period, served in its turn as the principal channel of discharge.† As the base of the delta is 200 miles in length, it must happen that, as often as the great volume of river-water is thrown into the sea by a new mouth, the sea will at one point be converted from salt to fresh, and at another from fresh to salt; for, with the excep-

* Mantell, Geol. of Sussex, p. 285; Trans, vol. iii. part i. p. 201, 2nd series. also Catalogue of Org. Rem., Geol. . I. p. 469.

tion of those parts where the principal discharge takes place, the salt water not only washes the base of the delta, but enters far into every creek and lagoon. It is evident, then, that repeated alternations of beds containing freshwater shells, with others filled with marine exuviæ, may here be formed. It has also been shown by artesian borings at Calcutta (see Vol. I. p. 476) that the delta once extended much farther than now into the gulf, and that the river is only recovering from the sea the ground which had been lost by subsidence at some former period. Analogous phenomena must sometimes be occasioned by such alternate elevation and depression as have occurred in modern times in the delta of the Indus.* But the subterranean movements affect a small number only of the deltas formed at one period on the globe; whereas the silting up of some of the arms of great rivers, and the opening of others, and the consequent variation of the points where the chief volume of their waters is discharged into the sea, are phenomena common to almost every delta.

The variety of species of Testacea contained in the recent calcareous marl of Scotland, before mentioned, is very small, but the abundance of individuals extremely great, a circumstance very characteristic of freshwater and brackish formations in general, as compared to marine; for in the latter, as is seen on sea-beaches, coral-reefs, or in the bottom of seas examined by dredging, wherever the individual shells are exceedingly numerous, there rarely fails to be a vast variety of species.

IMBEDDING OF THE REMAINS OF MARINE PLANTS AND ANIMALS.

Marine plants.—The large banks of drift sea-weed which occur on each side of the equator in the Atlantic, Pacific, and Indian oceans, were before alluded to.† These, when they subside, may often produce considerable beds of vegetable matter. In Holland, sub-marine peat is derived from Fuci. and on parts of our own coast from sea-wrack (*Zostera marina*).

* Page 99. † Page 395.

In places where Algæ do not generate peat, they may nevertheless leave traces of their form imprinted on argillaceous and calcareous mud, as they are usually very tough in their texture.

Sea-weeds are often cast up in such abundance on our shores during heavy gales, that we cannot doubt that occasionally vast numbers of them are imbedded in littoral deposits now in progress. We learn from the researches of Dr. Forchhammer, that besides supplying in common with land-plants the materials of coal, the Algæ must give rise to important chemical changes in the composition of strata in which they are imbedded. These plants always contain sulphuric acid, and sometimes in as large a quantity as 8½ per cent., combined with potash: magnesia also and phosphoric acid are constant ingredients. Whenever large masses of sea-weeds putrefy in contact with ferruginous clay, sulphuret of iron, or iron pyrites, is formed by the union of the sulphur of the plants with the iron of the clay. Many of the mineral characteristics of ancient rocks, especially the alum slates, and the pyrites which occur in clay slate, and the fragments of anthracite in marine strata, may be explained by the decomposition of fucoids or sea-weeds.*

Imbedding of cetacea.—It is not uncommon for the larger Cetacea, which can float only in a considerable depth of water, to be carried during storms or high tides into estuaries, or upon low shores, where, upon the retiring of high water, they are stranded. Thus a narwal (*Monodon monoceros*) was found on the beach near Boston in Lincolnshire, in the year 1800, the whole of its body buried in the mud. A fisherman going to his boat saw the horn, and tried to pull it out, when the animal began to stir itself.† An individual of the common whale (*Balæna mysticetus*), which measured 70 feet, came ashore near Peterhead, in 1682. Many individuals of the genus Balænoptera have met the same fate. It will be sufficient to refer to those cast on shore in the Firth of Forth near Burntisland, and at Alloa, recorded by Sibbald and Neill. The other individual

* Forchhammer Report British Assoc. 1844.

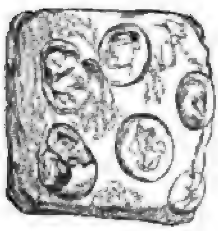
† Fleming's Brit. Animals, p. 37; in which work other cases are enumerated.

mentioned by Sibbald, as having come ashore at Boyne, in Banffshire, was probably a razor-back. Of the genus Catodon (*Cachalot*), Ray mentions a large one stranded on the west coast of Holland in 1598, and the fact is also commemorated in a Dutch engraving of the time of much merit. Sibbald, too, records that a herd of Cachalots, upwards of 100 in number, were found stranded at Cairston, in Orkney. The dead bodies of the larger Cetacea are sometimes found floating on the surface of the waters, as was the case with the immense whale exhibited in London in 1831. And the carcass of a sea-cow or Lamantine (*Halicora*) was, in 1785, cast ashore near Leith.

To some accident of this kind we may refer the position of the skeleton of a whale, 78 feet long, which was found at Airthie, on the Forth, near Stirling, imbedded in clay 20 feet higher than the surface of the highest tide of the river Forth at the present day. From the situation of the Roman station and causeways at a small distance from the spot, it is concluded that the whale must have been stranded there at a period prior to the Christian era.*

Marine reptiles. — Some singular fossils have been discovered in the Island of Ascension in a stone said to be continually forming on the beach, where the waves throw up small rounded fragments of shells and corals, which, in the course of time, become firmly agglutinated together, and constitute a stone used largely for building and making lime. In a quarry on the NW. side of the island, about 100 yards from the sea, some fossil eggs of turtles have been discovered in the hard rock thus formed. The eggs must have been nearly hatched at the time when they perished; for the bones of the young turtle are seen in the interior, with their shape fully developed, the interstices between the bones being entirely filled with grains of sand, which are cemented together, so

Fig. 150.



Fossil eggs of turtles from the Island of Ascension.†

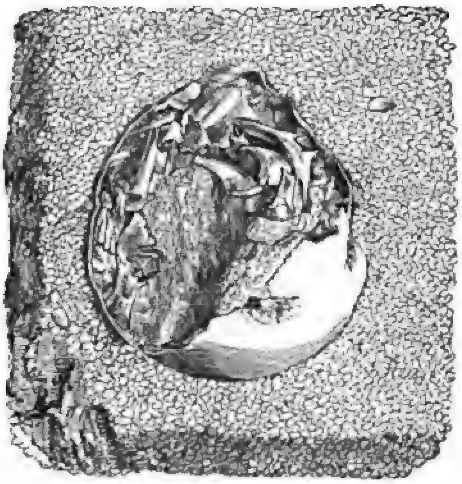
* Quart. Journ. of Lit. Sci., &c., No. xv. p. 172. Oct. 1819

† This specimen has been presented by Mr. Lonsdale to the Geological Society of London.

that when the egg-shells are removed perfect casts of their form remain in stone. In the single specimen here figured (fig. 150), which is only five inches in its longest diameter, no less than seven eggs are preserved.*

To explain the state in which they occur fossil, it seems necessary to suppose that after the eggs were almost hatched in the warm sand, a great wave threw upon them so much more sand as to prevent the rays of the sun from penetrating, so that the yolk was chilled and deprived of vitality. The shells were perhaps slightly broken at the same time, so that

Fig. 151.



One of the eggs in fig. 150, of the natural size, showing the bones of the fœtus which had been nearly hatched.

small grains of sand might gradually be introduced into the interior by water as it percolated through the beach.

Marine testacea.—The aquatic animals and plants which inhabit an estuary are liable, like the trees and land animals which people the alluvial plains of a great river, to be swept from time to time far into the deep; for as a river is per-

* The most conspicuous of the bones represented within the shell in fig. 151, appear to be the clavicle and coracoid bone. They are hollow; and for this reason resemble, at first sight, the bones of birds rather than of reptiles; for the latter have no medullary cavity. Prof. Owen, in order to elucidate this point, dissected for me a very young turtle, and found that the exterior portion only of the bones was ossified, the interior being still filled with cartilage.

petually shifting its course, and undermining a portion of its banks with the forests which cover them, so the marine current alters its direction from time to time, and bears away the banks of sand and mud against which it turns its force. These banks may consist in great measure of shells peculiar to shallow and sometimes brackish water, which may have been accumulating for centuries, until at length they are carried away and spread out along the bottom of the sea, at a depth at which they could not have lived and multiplied. Thus littoral and estuary shells are more frequently liable, even than freshwater species, to be intermixed with the exuviæ of pelagic tribes.

After the storm of February 4, 1831, when several vessels were wrecked in the estuary of the Forth, the current was directed against a bed of oysters with such force, that great heaps of them were thrown *alive* upon the beach, and remained above high-water mark. I collected many of these oysters, as also the common eatable whelks (*Buccinum*), thrown up with them, and observed that, although still living, their shells were worn by the long attrition of sand which had passed over them as they lay in their native bed, and which had evidently not resulted from the mere action of the tempest by which they were cast ashore. From these facts we learn that the union of the two parts of a bivalve shell does not prove that it has not been transported to a distance; and when we find shells worn, and with all their prominent parts rubbed off, they may still have been imbedded where they grew.

Burrowing shells.—It sometimes appears extraordinary, when we observe the violence of the breakers on our coast, and see the strength of the current in removing cliffs, and sweeping out new channels, that many tender and fragile shells should inhabit the sea in the immediate vicinity of this turmoil. But a great number of the bivalve Testacea, and many also of the turbinated univalves, burrow in sand or mud. The Solen and the Cardium, for example, which are usually found in shallow water near the shore, pierce through a soft bottom without injury to their shells; and the Pholas can drill a cavity through mud of considerable

hardness. These and many other shells can sink, when alarmed, with considerable rapidity, often to the depth of several feet, and can also penetrate upwards again to the surface, if a mass of matter be heaped upon them. The hurricane, therefore, may expend its fury in vain, and may sweep away even the upper part of banks of sand or mud, or may roll pebbles over them, and yet these Testacea may remain below secure and uninjured.

Depths at which organic bodies may become fossil.—Captain Vidal ascertained in 1834, by soundings made off Tory Island, on the north coast of Ireland, that Crustacea, Starfish, and Testacea occurred at various depths between 50 and 100 fathoms; and he drew up Dentalia from the mud of Galway Bay, in 230 and 240 *fathoms* water. The same hydrographer discovered on the Rockhall Bank large quantities of shells at depths varying from 45 to 190 fathoms. These shells were evidently recent, as they retained their colours. In the same region a bed of fish-bones was observed extending for two miles along the bottom of the sea in 10 and 90 fathoms water. At the eastern extremity also of Rockhall Bank fish-bones were met with, mingled with pieces of fresh shell, at the depth of 235 fathoms.

Analogous formations are in progress in the submarine tracts extending from the Shetland Isles to the north of Ireland, wherever soundings can be procured. A continuous deposit of sand and mud, replete with broken and entire shells, Echini, &c., has been traced for upwards of twenty miles to the eastward of the Faroe Islands, usually at the depth of from 40 to 100 fathoms. In one part of this tract (lat. 61° 50′, long. 6° 30′) fish-bones occur in extraordinary profusion, so that the lead cannot be drawn up without some vertebræ being attached. This 'bone bed,' as it was called by our surveyors, is three miles and a half in length, and forty-five fathoms under water, and contains a few shells intermingled with the bones.

In the British seas, the shells and other organic remains lie in soft mud or loose sand and gravel whereas, in the bed of the Adriatic, Donati found them frequently enclosed in stone of recent origin. This is precisely the difference in

character which we might have expected to exist between the British marine formations now in progress and those of the Adriatic; for calcareous and other mineral springs abound in the Mediterranean and lands adjoining, while they are almost entirely wanting in our own country.

I have already adverted to the eight regions of different depths in the Ægean Sea, each characterised by a peculiar assemblage of shells, which have been described by Professor E. Forbes, who explored them by dredging (see above, p. 376), and who conjectured from the rate at which the marine fauna grew scantier with the depth, that the zero of animal life would be reached in that sea at about 300 fathoms. This speculation has proved correct in reference to the Mediterranean in general, although mollusca, corals, and bryozoa have since been brought up, adhering to the French telegraph cable between Sardinia and Algiers, from much greater depths.* Messrs. Carpenter and Gwyn Jeffreys, in 1870, examined carefully the mud brought up from the bottom at points below 400 fathoms off the coast of Africa, between Ceuta and Oran, and elsewhere, in the western basin of the Mediterranean, and they found that it consisted of a very fine yellowish sand, mixed with a bluish clay, quite devoid of organic substances, and therefore called by them azoic. This entire absence of life cannot, as they observe, be ascribed simply to the depth, because, as above stated, life has been detected far lower in the Mediterranean. Dr. Carpenter suggests, therefore, that the extremely fine mud brought down by the Rhone,† sinking very gradually to the bottom of the Mediterranean, may be prejudicial to the respiration of various invertebrates, for it is known that oyster-beds cannot be established in situations to which fine mud is brought by any fluvial or tidal current.

In regard to the extreme depth at which life can exist in the ocean, I had already mentioned in my last edition, that Dr. Hooker, in his Antarctic voyage with Captain Sir J. C. Ross, established the fact from soundings made off Victoria Land between lats. 71° and 78° south, that the bottom of the

* Ann. des Sciences Nat., 4 Series, vol. xv. p. 3.
† See Vol. I. p. 423.

ocean was inhabited, at depths of from 200 to 400 fathoms, by crustacea, mollusca, serpulæ, sponges, and other invertebrata,* and Sir Leopold McClintock and Dr. Wallich, in 1860, found living starfish at the depth of a thousand fathoms midway between Greenland and Iceland.

The late deep-sea dredgings carried on in the Atlantic by Messrs. Carpenter, Gwyn Jeffreys, and Wyville Thomson in the 'Porcupine' (1868–71), have still farther extended the downward limit, Professor Wyville Thomson having found life existing in the Bay of Biscay at a depth of 15,000 feet, or as far below the sea level as Mont Blanc is above it. The sounding alluded to was made in lat. 47° 38′ N., long. 12° 08′ W., about 250 miles west of Ushant, a small island on the north-west coast of France. The dredge brought up in the ooze, mollusca (*Pleurotoma* and *Dentalium*), crustacea, and echinodermata, among which was a crinoid referable to the Apiocrinite type which flourished during the Oolitic period.†

In all such cases, it is only necessary that there should be some deposition of sedimentary matter, however minute, such as may be supplied by rivers draining a continent, or currents preying on a line of cliffs, or melting icebergs loaded with mud, sand, and boulders, in order that stratified formations, hundreds of feet in thickness, and replete with organic remains, should result in the course of ages.

We frequently observe, on the sea-beach, very perfect specimens of fossil shells, quite detached from their matrix, which have been washed out of older formations, constituting the sea-cliffs. They may be all of extinct species, like the Eocene freshwater and marine shells strewed over the southern shores of Hampshire, yet when they become mingled with the shells of the present period, and buried in the same deposits of mud and sand, they might appear, if upraised and examined by future geologists, to have been all of the same age. That such intermixture and blending of organic remains of different ages have actually taken place in former times, is unquestionable, though the occurrence appears to be very local and exceptional. It is, however, a

* 'Antiquity of Man,' p. 268, and Appendix H., p. 528.

† Royal Soc. Proc. vol. xviii. p. 429. 1870.

class of accidents more likely than almost any other to lead to serious anachronisms in geological chronology.

Many have thought that the recent discovery of the coexistence of warm and cold areas within twenty miles of each other, and in the same latitude in the North Atlantic, above alluded to,* would in like manner tend to weaken the value of paleontological evidence as bearing on geological classification. Such fears need not be entertained, for although the current coming from the South and supposed to be connected with the Gulf-stream differed as a whole in its fauna from the Arctic current, the waters of the one containing globigerinæ and vitreous sponges, and those of the other Northern forms of echinodermata and crustacea, yet Mr. Gwyn Jeffreys found that of fifty-five species of mollusca dredged up in the cold area, forty-four were common to the warm area, which possessed no associated peculiar species.† The mollusca, therefore, a class of invertebrata on which geologists are chiefly in the habit of founding their classification, being so many of them common to the two areas, would prevent any serious chronological error in a future comparison of the fossils of the two regions.

* Vol. I. p. 503. † Prestwich Geol. Soc. Add., 1871, p. 47.

CHAPTER XLIX.

FORMATION OF CORAL REEFS.

GROWTH OF CORAL CHIEFLY CONFINED TO TROPICAL REGIONS—PRINCIPAL GENERA OF CORAL-BUILDING ZOOPHYTES—THEIR RATE OF GROWTH—SELDOM FLOURISH AT GREATER DEPTHS THAN TWENTY FATHOMS—ATOLLS OR ANNULAR REEFS WITH LAGOONS—MALDIVE ISLES—ORIGIN OF THE CIRCULAR FORM—CORAL REEFS NOT BASED ON SUBMERGED VOLCANIC CRATERS—MR. DARWIN'S THEORY OF SUBSIDENCE IN EXPLANATION OF ATOLLS, ENCIRCLING AND BARRIER REEFS—WHY THE WINDWARD SIDE OF ATOLLS HIGHEST—SUBSIDENCE EXPLAINS WHY ALL ATOLLS ARE NEARLY ON ONE LEVEL—ALTERNATE AREAS OF ELEVATION AND SUBSIDENCE—ORIGIN OF OPENINGS INTO THE LAGOONS—SIZE OF ATOLLS AND BARRIER REEFS—OBJECTION TO THE THEORY OF SUBSIDENCE CONSIDERED—COMPOSITION, STRUCTURE, AND STRATIFIED ARRANGEMENT OF ROCKS NOW FORMING IN CORAL REEFS—LIME WHENCE DERIVED—SUPPOSED INCREASE OF CALCAREOUS MATTER IN MODERN EPOCHS CONTROVERTED—CONCLUDING REMARKS.

THE powers of the organic creation in modifying the form and structure of the earth's crust are most conspicuously displayed in the labours of the coral animals. We may compare the operation of these zoophytes in the ocean to the effects produced on a smaller scale upon the land by the plants which generate peat. In the case of the Sphagnum, the upper part vegetates while the lower portion is entering into a mineral mass, in which the traces of organisation remain when life has entirely ceased. In corals, in like manner, the more durable materials of the generation that has passed away serve as the foundation on which the living animals continue to rear a similar structure.

The stony part of the lamelliform zoophyte may be likened to an internal skeleton; for it is always more or less surrounded by a soft animal substance capable of expanding itself; yet, when alarmed, it has the power of contracting and drawing itself almost entirely into the cells and hollows of the hard coral. Although oftentimes beautifully coloured in their own element, the soft parts become when taken from

the sea nothing more in appearance than a brown slime spread over the stony nucleus.*

The growth of those corals which form reefs of solid stone is entirely confined to the warmer regions of the globe, rarely extending beyond the tropics more than two or three degrees, except under peculiar circumstances, as in the Bermuda Islands, in lat. 32° N., where the Atlantic is made warmer by the Gulf-stream. The Caribbean seas are very coralliferous. The Pacific Ocean, throughout a space comprehended between the thirtieth parallels of latitude on each side of the equator, is extremely productive of coral; as also are the Arabian and Persian Gulfs. Coral is also abundant in the sea between the coast of Malabar and the island of Madagascar. Flinders describes a reef of coral on the east coast of New Holland as having a length of nearly 1,000 miles, and as being in one part unbroken for a distance of 350 miles. Some groups of coral islands in the Pacific are from 1,100 to 1,200 miles in length, by 300 or 400 in breadth, as the Dangerous Archipelago, for example, and that called Radack by Kotzebue; but the islands within these spaces are always small points, and often very thinly sown.

Fig. 152.

Mæandrina labyrinthica, Lam.
Syn. *Cœloria labyrinthica*
M. Edw. & J. Haimes.

MM. Duchassaing and Jean Michelotti have lately written a concise account of the distribution of reef corals in relation to the depth of the sea.† A certain number of zoophytes are littoral and are left uncovered by every low tide—for instance, species of the genera *Zoanthes* and *Palythoa*. In shallow spots where a certain depth of water always covers the corals, the species of *Porites*, *Astræa*, *Madrepora*, *Solenastræa*, and *Phyllangia*, flourish. The *Mæandrinæ* are sometimes left uncovered. All

* Ehrenberg, Nat. und Bild. der Coralleninseln, &c., Berlin, 1834.

† Supplément au Mémoire sur les Coralliaires des Antilles. Mem. della Reale Accad. delle Scienze di Torino, série II. tom. xxiii.

these may be termed sub-littoral. At a depth of from 6 to 10 feet the genera Mussa, Colpophyllia, Lithophyllia, Symphyllia, Millepora, &c., are found, and at the depth of from 10 to 20 feet the species of Dichocœnia, Stephanocœnia, and Desmophyllum flourish.

The distribution of particular species, in regard to the depth of water in which they grow, is remarkably uniform. According to Mr. Darwin, as will appear in the sequel, the reef-building corals rarely live at a depth exceeding 120 feet, but M. Duchassaing obtained some species of stony corals at depths of from 600 to 900 feet in the Caribbean Sea. In temperate climates such species as the *Caryophyllia Smythi*, Stokes, are sub-littoral; but Dr. Duncan reminds me, and the fact is of no small geological significance when we are reasoning on extinct forms, that the closely allied species *C. borealis* now lives in deep water off the Shetlands. I learn from Dr. Duncan that the coral fauna of the deep and abyssal sea to a depth of 1,750 fathoms presents species differing in their general anatomy from those which enter into the composition of reefs and atolls. The deep-sea corals do not unite in masses, but are usually simple, solitary, and when aggregated are branched. None of these forms possess the cellular cœnenchyma between the corallites which strengthen the massive reef-builders. All the deep-sea corals of modern and of past times thus differ from reef-builders.*

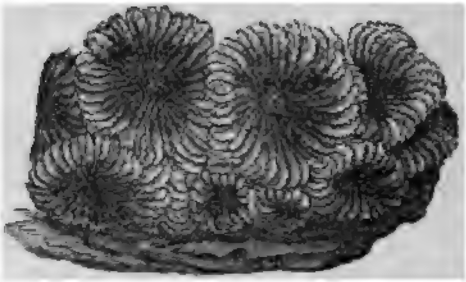
Of the numerous zoophytes which are engaged in the production of coral banks, some of the most common belong to the Lamarckian genera Astræa, Porites, Madrepora, Millepora, Pocillopora, and Mæandrina. (See figs. p. 590.)

Rate of the growth of coral.—Very different opinions have been entertained in regard to the rate at which coral reefs increase. In Captain Beechey's late expedition to the Pacific, no positive information could be obtained of any channel having been filled up within a given period; and it seems established, that several reefs had remained for more than half a century at about the same depth from the surface.

Ehrenberg also questions the fact of channels and harbours having been closed up in the Red Sea by the rapid

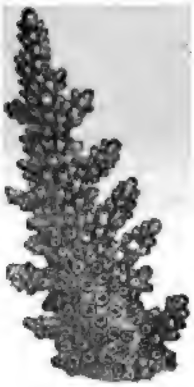
* P. M. Duncan, Coral Faunas of Europe, Quart. Geol. Journ. Soc.

Fig. 153.
Genera of Zoophytes most common in coral reefs.



Astræa dipsacea, Ehrenb. sp. Syn. *Acanthastræa grandis*, Milne Edw. & J. Haimes.

Fig. 154.

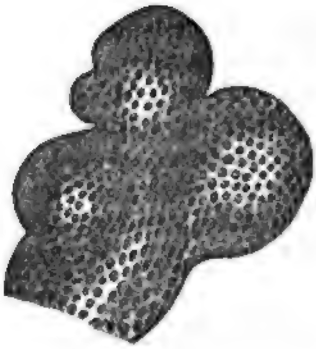


Extremity of branch of *Madrepora muricata*, Lin.

Fig. 155.

Caryophyllia fastigiata, Lam. Syn. *Eusmilia fastigiata*, Milne Edw. & J. Haimes.

Fig. 156.



Porites clavaria, Lam.

Fig. 157.

Oculina hirtella, Lam.

increase of coral limestone. He supposes the notion to have arisen from the circumstance of havens having been occasionally filled up in some places with coral sand, in others with large quantities of ballast of coral rock thrown down from vessels.

The natives of the Bermuda Islands point out certain corals now growing in the sea, which, according to tradition, have been living in the same spots for centuries. It is supposed that some of them may vie in age with the most ancient trees of Europe. Ehrenberg also observed single corals of the genera Mæandrina and Favia, having a globular form, from 6 to 9 feet in diameter, 'which must (he says) be of immense antiquity, probably several thousand years old, so that Pharaoh may have looked upon these same individuals in the Red Sea.'* They certainly imply, as he remarks, that the reef on which they grow has increased at a very slow rate. After collecting more than 100 species, he found none of them covered with parasitic zoophytes, nor any instance of a living coral growing on another living coral. To this repulsive power which they exert whilst living, against all others of their own class, we owe the beautiful symmetry of some large Mæandrinæ, and other species which adorn our museums. Yet Balani and Serpulæ can attach themselves to the dermal tissues of living corals, and holes are excavated in them by boring mollusks.

At the island called Taaopoto, in the South Pacific, the anchor of a ship, wrecked about 50 years before, was observed in seven fathoms' water, still preserving its original form, but entirely incrusted by coral.† This fact would seem to imply a slow rate of augmentation; but to form a correct estimate of the average rate must be very difficult, since it must vary not only according to the species of coral, but according to the circumstances under which each species may be placed; such, for example, as the depth from the surface, the quantity of light, the temperature of the water, its freedom from sand or mud, or the absence or presence of breakers, which is favourable to the growth of some kinds and fatal to that

* See Ehrenberg's work above cited, p. 751.

† Stuchbury, West of England Journal, No. i. p. 49.

of others. It should also be observed that the apparently stationary condition of some coral reefs, which according to Beechey have remained for centuries at the same depth under water, may be due to subsidence, the upward growth of the coral having been just sufficient to keep pace with the sinking of the solid foundation on which the zoophytes have built. We shall afterwards see how far this hypothesis is borne out by other evidence in the regions of annular reefs or atolls.

In one of the Maldive Islands a coral reef, which, within a few years, existed as an islet bearing cocoa-nut trees, was found by Lieutenant Prentice, '*entirely covered with live coral and madrepore.*' The natives stated that the islet had been washed away by a change in the currents, and it is clear that a coating of growing coral had been formed in a short time.* Experiments, also, of Dr. Allan, on the east coast of Madagascar, prove the possibility of coral growing to a thickness of three feet in about half a year; † so that the rate of increase may, under favourable circumstances, be very far from slow.

It must not be supposed that the calcareous masses termed coral reefs are exclusively the work of zoophytes: a great variety of shells, and, among them, some of the largest and heaviest of known species, contribute to augment the mass. In the South Pacific, great beds of Serpulæ, oysters, mussels, *Pinnæ marinæ*, *Chamæ* (or *Tridacnæ*), and other shells, cover in profusion almost every reef; and on the beach of coral islands are seen the shells of echini and broken fragments of crustaceous animals. Large shoals of fish are also discernible through the clear blue water, and their teeth and hard palates cannot fail to be often preserved although their soft cartilaginous bones may decay.

It was the opinion of the German naturalist Forster, in 1780, after his voyage round the world with Captain Cook, that coral animals had the power of building up steep and almost perpendicular walls from great depths in the sea, a notion afterwards adopted by Captain Flinders and others;

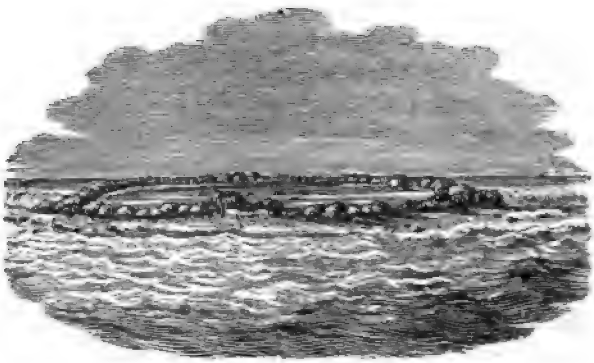
* Darwin's Coral Reefs, p. 77. † Ibid. p. 78.

but it is now very generally believed that most of these zoophytes cannot live in water of great depths.

Mr. Darwin has come to the conclusion, that those species which are most effective in the construction of reefs, rarely flourish at a greater depth than 20 fathoms, or 120 feet. In some lagoons, however, where the water is but little agitated, there are, according to Kotzebue, beds of living coral in 25 fathoms' water, or 150 feet; but these may perhaps have begun to live in shallower water, and may have been carried downwards by the subsidence of the reef. There are also various species of zoophytes, and among them some which are provided with calcareous as well as horny stems, which live in much deeper water, even in some cases to a depth of 180 fathoms; but these do not appear to give origin to stony reefs.

There is every variety of form in coral reefs, but the most remarkable and numerous in the Pacific consist of circular

Fig. 158.



View of Whitsunday Island. (Capt. Beechey.)*

or oval strips of dry land, enclosing a shallow lake or lagoon of still water, in which zoophytes and mollusca abound. The annular reefs just raise themselves above the level of the sea, and are surrounded by a deep and often unfathomable ocean.

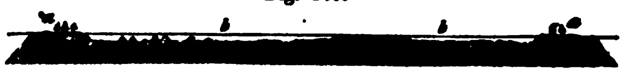
In the annexed cut (fig. 158), one of these circular islands

* Voyage to the Pacific, &c. in 1825–28.

is represented, just rising above the waves, covered with the cocoa-nut and other trees, and enclosing within a lagoon of tranquil water, whose vivid green colour contrasts strikingly with the deep blue of the surrounding ocean.

The accompanying section will enable the reader to comprehend the usual form of such islands. (Fig. 159.)

Fig. 159.



Section of a Coral Island.

a, a. Habitable part of the island, consisting of a strip of coral, enclosing the lagoon.
b, b. The lagoon.

The subjoined cut (fig. 160) exhibits a small part of the section of a coral island on a larger scale.

Fig. 160.

Section of part of a Coral Island.

a, b. Habitable part of the island.
b, b. Slope of the side of the island, plunging at an angle of forty-five to the depth of fifteen hundred feet.
c, c. Part of the lagoon.
d, d. Knolls of coral in the lagoon, with overhanging masses of coral resembling the capitals of columns.

Of thirty-two of these coral islands visited by Beechey in his voyage to the Pacific, twenty-nine had lagoons in their centres. The largest was 30 miles in diameter, and the smallest less than a mile. All were increasing their dimensions by the active operations of the lithophytes, which appeared to be gradually extending and bringing the immersed parts of their structure to the surface. The scene presented by these annular reefs is equally striking for its singularity and beauty. A strip of land a few hundred yards wide is covered by lofty cocoa-nut trees, above which is the blue vault of heaven. This band of verdure is bounded by a beach of glittering white sand, the outer margin of which is encircled with a ring of snow-white breakers, beyond which are the dark heaving waters of the ocean. The inner beach encloses the still clear water of the lagoon, resting in its greater

part on white sand, and when illuminated by a vertical sun, of a most vivid green.* Certain species of zoophytes abound most in the lagoon, others on the exterior margin, where there is a great surf. 'The ocean,' says Mr. Darwin, 'throwing its breakers on these outer shores, appears an invincible enemy, yet we see it resisted and even conquered by means which at first seem most weak and inefficient. No periods of repose are granted, and the long swell caused by the steady action of the trade wind never ceases. The breakers exceed in violence those of our temperate regions, and it is impossible to behold them without feeling a conviction that rocks of granite or quartz would ultimately yield and be demolished by such irresistible forces. Yet these low insignificant coral islets stand and are victorious, for here another power, as antagonist to the former, takes part in the contest. The organic forces separate the atoms of carbonate of lime one by one from the foaming breakers, and unite them into a symmetrical structure; myriads of architects are at work night and day, month after month, and we see their soft and gelatinous bodies through the agency of the vital laws conquering the great mechanical power of the waves of an ocean, which neither the art of man, nor the inanimate works of nature, could successfully resist.'†

As the coral animals require to be continually immersed in salt water, they cannot raise themselves by their own efforts above the level of the lowest tides. The manner in which the reefs are converted into islands above the level of the sea is thus described by Chamisso, a naturalist who accompanied Kotzebue in his voyages :—'When the reef,' says he, 'is of such a height that it remains almost dry at low water, the corals leave off building. Above this line a continuous mass of solid stone is seen composed of the shells of mollusks and echini, with their broken-off prickles and fragments of coral, united by calcareous sand, produced by the pulverisation of shells. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places, and the force of the waves is thereby enabled to separate and lift

* Darwin's Journal, &c., p. 540, and new edit., of 1845, p. 453.
† Ibid. pp. 547, 548, and 2nd edit., of 1845, p. 460.

blocks of coral, frequently six feet long and three or four in thickness, and throw them upon the reef, by which means the ridge becomes at length so high that it is covered only during some seasons of the year by the spring tides. After this the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves a soil upon which they rapidly grow, to overshadow its dazzling white surface. Entire trunks of trees, which are carried by currents from other countries and islands, find here, at length, a resting-place after their long wanderings: with these come some small animals, such as insects and lizards, as the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; stray land-birds take refuge in the bushes; and, at a much later period, when the work has been long since completed, man appears and builds his hut on the fruitful soil.'*

In the above description the solid stone is stated to consist of shell and coral, united by sand; but masses of very compact limestone are also found even in the uppermost and newest parts of the reef, such as could only have been produced by chemical precipitation. Professor Agassiz also informs me that his observations on the Florida reefs (which confirm Darwin's theory of atolls to be mentioned in the sequel) have convinced him that large blocks are loosened, not by shrinkage in the sun's heat, as Chamisso imagined, but by innumerable perforations of lithodomi and other boring testacea. The carbonate of lime may have been principally derived from the decomposition of corals and testacea; for when the animal matter undergoes putrefaction, the calcareous residuum must be set free under circumstances very favourable to precipitation, especially when there are other calcareous substances, such as shells and corals, on which it may be deposited. Thus organic bodies may be enclosed in a solid cement, and become portions of rocky masses.†

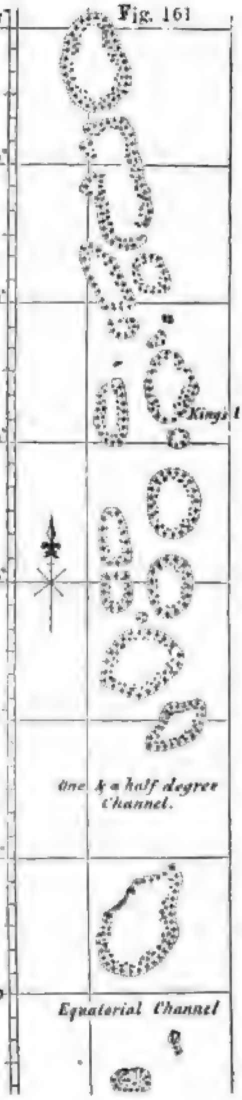
The width of the circular strip of dead coral forming the islands explored by Captain Beechey, exceeded in no instance half a mile from the usual wash of the sea to the edge of the

* Kotzebue's Voy., 1815–18, vol. iii. pp. 331–333.

† Stuchbury, West of Eng. Journ., No. i. p. 50, and P. M. Duncan, Quart. Journ. Geol. Soc., Nov. 1864, p. 360.

lagoon, and, in general, was only about three or four hundred yards.* The depth of the lagoons is various; in some, entered by Captain Beechey, it was from 20 to 38 fathoms. The two other peculiarities which are most characteristic of the annular reef or atoll are first, that the strip of dead coral is invariably highest on the windward side, and secondly, that there is very generally an opening at some point in the reef affording a narrow passage, often of considerable depth, from the sea into the lagoon. The origin of this passage and its connection with the subsidence of the coral areas will be considered (p. 608).

Fig. 161



Maldive and Laccadive Isles.—The reefs and islets called the Maldives (see fig. 161), situated in the Indian Ocean, to the south-west of Malabar, form a chain 470 geographical miles in length, running due north and south, with an average breadth of about 50 miles. It is composed throughout of a series of circular assemblages of islets, all formed of coral, the larger groups being from 40 to 90 miles in their longest diameter. Captain Horsburgh, whose chart of these islands is subjoined, states, that outside of each circle or *atoll*, as it is termed, there are coral reefs sometimes extending to the distance of two or three miles, beyond which there are no soundings at immense depths. But in the centre of each atoll there is a lagoon from 15 to 49 fathoms deep. In the channels between the atolls no soundings can usually be obtained at the depth of 150 or even 250 fathoms, but during Captain Moresby's survey, sound-

* Captain Beechey, part i. p. 188.

ings were struck at 150 and 200 fathoms, the only instances as yet known of the bottom having been reached, either in the Indian or Pacific oceans, in a space intervening between two separate and well characterised atolls.

The singularity in the form of the atolls of this archipelago consists in their being made up, not of one continuous circular reef, but of a ring of small coral islets sometimes more than a hundred in number, each of which is a ring-shaped strip of coral surrounding a lagoon of salt water. To account for the origin of these, Mr. Darwin supposes the larger annular reef to have been broken up into a number of fragments, each of which acquired its peculiar configuration under the influence of causes similar to those to which the structure of the parent atoll has been due. Many of the minor rings are no less than three, and even five miles in diameter, and some are situated in the midst of the principal lagoon; but this happens only in cases where the sea can enter freely through breaches in the outer or marginal cave.

The rocks of the Maldives are composed of limestone formed of broken shells and corals, such as may be obtained in a loose state from the beach, and which is seen when exposed for a few days to the air to become hardened. The limestone is sometimes observed to be an aggregate of broken shells, corals, pieces of wood, and shells of the cocoa-nut.*

The Laccadive Islands run in the same line with the Maldives, on the north, as do the islands of the Chagos Archipelago, on the south; so that these may be continuations of the same chain of submerged mountains, crested in a similar manner by coral limestones.

Origin of the circular form—not volcanic.—The circular and oval shape of so many reefs, each having a lagoon in the centre, and being surrounded on all sides by a deep ocean, naturally suggested the idea that they were nothing more than the crests of submarine volcanic craters overgrown by coral: and this theory I myself advocated in the earlier

* Captain Moresby on the Maldives, Journ. Roy. Geograph. Soc., vol. v. part ii. p. 400.

editions of this work. Although I am now about to show that it must be abandoned, it may still be instructive to point out the grounds on which it was formerly embraced. In the first place, it had been remarked that there were many active volcanos in the coral region of the Pacific, and that in some places, as in Gambier's group, rocks composed of porous lava rise up in a lagoon bordered by a circular reef, just as the two cones of eruption called the Kaimenis have made their appearance in the times of history within the circular gulf of Santorin.* It was also observed that as in S. Shetland, Barren Island, and others of volcanic origin, there is one narrow breach in the walls of the outer cone by which ships may enter a circular gulf, so in like manner there is often a single deep passage leading into the lagoon of a coral island, the lagoon itself seeming to represent the hollow or gulf just as the ring of dry coral recalls to our minds the rim of a volcanic crater. More lately, indeed, Mr. Darwin has shown that the numerous volcanic craters of the Galapagos Archipelago in the Pacific have all of them their southern sides the lowest, or in many cases quite broken down, so that if they were submerged and incrusted with coral, they would resemble true atolls in shape.†

Another argument which I adduced when formerly defending this doctrine was derived from Ehrenberg's statement, that some banks of coral in the Red Sea were square, while many others were ribbon-like strips, with flat tops, and without lagoons. Since, therefore, all the genera and many of the species of zoophytes in the Red Sea agreed with those which elsewhere construct lagoon islands, it followed that the stone-making zoophytes are not guided by their own instinct in the formation of annular reefs, but that this peculiar shape and the position of such reefs in the midst of a deep ocean must depend on the outline of the submarine bottom, which resembles nothing else in nature but the crater of a lofty submerged volcanic cone. The enormous size, it is true, of some atolls made it necessary for me to ascribe to the craters of many submarine volcanos a magnitude which was startling, and which had often been appealed to as a serious objection

* See above, p. 69.

† Darwin, Volcanic Islands, p. 113.

to the volcanic theory. That so many of them were of the same height, or just level with the water, did not present a difficulty so long as we remained ignorant of the fact that the reef-building species do not grow at greater depths than 25 fathoms.

May be explained by subsidence.—Mr. Darwin, after examining a variety of coral formations in different parts of the globe, was induced to reject the opinion that their shape represented the form of the original bottom. Instead of admitting that the ring of dead coral rested on a circular or oval ridge of rock, or that the lagoon corresponded to a pre-existing cavity, he advanced a new opinion, which must, at first sight, seem paradoxical in the extreme: namely, that the lagoon is precisely in the place once occupied by the highest part of a mountainous island, or, in other cases, by the top of a shoal.

The following is a brief sketch of the facts and arguments in favour of this new view:—Besides those rings of dry coral which enclose lagoons, there are others having a similar form and structure which encircle lofty islands. Of the latter kind is Vanikoro (see Map, fig. 65, p. 587, Vol. I.), celebrated on account of the shipwreck of La Peyrouse, where the coral reef runs at the distance of two or three miles from the shore, the channel between it and the land having a general depth of between 200 and 300 feet. This channel, therefore, is analogous to a lagoon, but with an island standing in the middle. In like manner in Tahiti we see a mountainous land, with everywhere round its margin a lake or zone of smooth salt water, separated from the ocean by an encircling reef of coral, on which a line of breakers is always foaming. So also New Caledonia, a long narrow island east of New Holland, composed partly of granite and partly of triassic sandstone, is surrounded by a reef 400 miles long. This reef encompasses not only the island itself, but a ridge of rocks which is prolonged in the same direction beneath the sea. No one, therefore, will contend for a moment that in this case the corals are based upon the rim of a volcanic crater, in the middle of which stands a mountain or island of granite or sandstone.

The great barrier reef, already mentioned as running parallel to the north-east coast of Australia for nearly 1,000 miles, is another most remarkable example of a long strip of coral running parallel to a coast. Its distance from the mainland varies from 20 to 70 miles, and the depth of the great arm of the sea thus enclosed is usually between 10 and 20 fathoms, but towards one end from 40 to 60. This great reef would extend much farther, according to Mr. Jukes, if the growth of coral were not prevented off the shores of New Guinea by a muddy bottom, caused by rivers charged with sediment which flow from the southern coast of that great island.*

Two classes of reefs, therefore, have now been considered; first, the atoll, and, secondly, the encircling and barrier reef, both agreeing perfectly in structure, and the sole difference lying in the absence in the case of the atoll of all land, and in the others the presence of land bounded either by an encircling or a barrier reef. But there is still a third class of reefs, called by Mr. Darwin 'fringing reefs,' which approach much nearer the land than those of the encircling and barrier class, and which indeed so nearly touch the coast as to leave nothing in the intervening space resembling a lagoon. 'That these reefs are not attached quite close to the shore appears to be the result of two causes; first, that the water immediately adjoining the beach is rendered turbid by the surf, and therefore injurious to all zoophytes; and, secondly, that the larger and efficient kinds only flourish on the outer edges amidst the breakers of the open sea.'†

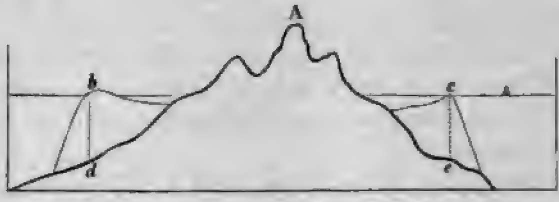
It will at once be conceded that there is so much analogy between the form and position of the strip of coral in the atoll, and in the encircling and barrier reef, that no explanation can be satisfactory which does not include the whole. If we turn, in the first place, to the encircling and barrier reefs, and endeavour to explain how the zoophytes could have found a bottom on which to begin to build, we are met at once with a great difficulty. It is a general fact, long since

* Quart. Journ. Geol. Soc. 4, xciii.

† Darwin's Journ., p. 557, 2nd edit. chap. 20, and Coral Islands, chapters 1, 2, 3.

remarked by Dampier, that high land and deep seas go together. In other words, steep mountains coming down abruptly to the sea-shore are generally continued with the same slope beneath the water. But where the reef, as at *b c* (fig. 162), is distant several miles from a steep coast, a line

Fig. 162.



Supposed section of an island with an encircling reef of coral.
A. The island.
b, *c*. Highest points of the encircling reef between which and the coast is seen a space occupied by still water.

drawn perpendicularly downwards from its outer edges *b c*, to the fundamental rock *d e*, must descend to a depth exceeding by several thousand feet the limits at which the efficient stone-building corals can exist, for we have seen that they cease to grow in water which is more than 120 feet deep. That the original rock immediately beneath the points *b c* is actually as far from the surface *d e*, is not merely inferred from Dampier's rule, but confirmed by the fact, that, immediately outside the reef, soundings are either not met with at all, or only at enormous depths. In short, the ocean is as deep as might have been anticipated in the neighbourhood of a bold coast; and it is obviously the presence of the coral alone which has given rise to the anomalous existence of shallow water on the reef and between it and the land.

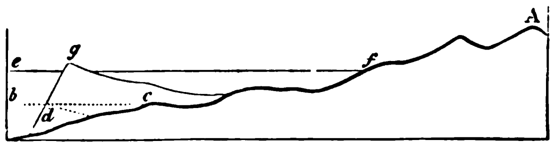
After studying in minute detail all the phenomena above described, Mr. Darwin has offered in explanation a theory now very generally adopted. The coral-forming polypi, he states, begin to build in water of a moderate depth, and, while they are yet at work, the bottom of the sea subsides gradually, so that the foundation of their edifice is carried downwards at the same time that they are raising the superstructure. If, therefore, the rate of subsidence be not too rapid, the growing coral will continue to build up to the surface;

the mass always gaining in height above its original base, but remaining in other respects in the same position. Not so with the land: each inch lost is irreclaimably gone; as it sinks the water gains foot by foot on the shore, till in many cases the highest peak of the original island disappears. What was before land is then occupied by the lagoon, the position of the encircling coral remaining unaltered, with the exception of a slight contraction of its dimensions.

In this manner are encircling reefs and atolls produced; and in confirmation of his views Mr. Darwin has pointed out examples which illustrate every intermediate state, from that of lofty islands such as Otaheite, encircled by coral, to that of Gambier's group, where a few peaks only of land rise out of a lagoon, and, lastly, to the perfect atoll, having a lagoon several hundred feet deep, surrounded by a reef rising deeply, from an unfathomed ocean.

If we embrace these views, it is clear, that in regions of growing coral a similar subsidence must give rise to barrier

Fig. 163.



reefs along the shores of a continent. Thus suppose A (fig. 163) to represent the north-east portion of Australia, and *b c* the ancient level of the sea, when the coral reef *d* was formed. If the land sink so that it is submerged more and more, the sea must at length stand at the level *e f*, the reef in the meantime having been enlarged and raised to the point *g*. The distance between the shore *f*, and the barrier reef *g*, is now much greater than originally between the shore *c* and the reef *d*, and the longer the subsidence continues the farther will the coast of the mainland recede.

When the first edition of this work appeared in 1831, several years before Mr. Darwin had investigated the facts on which this theory is founded, I had come to the opinion that the land was subsiding at the bottom of those parts of

the Pacific where atolls are numerous, although I failed to perceive that such a subsidence, if conceded, would equally solve the enigma as to the form both of annular and barrier reefs.

I shall cite the passage referred to, as published by me in 1831:—'It is a remarkable circumstance that there should be so vast an area in Eastern Oceanica, studded with minute islands, without one single spot where there is a wider extent of land than belongs to such islands as Otaheite, Owhyhee, and a few others, which either have been or are still the seats of active volcanos. If an equilibrium only were maintained between the upheaving and depressing force of earthquakes, large islands would very soon be formed in the Pacific; for, in that case, the growth of limestone, the flowing of lava, and the ejection of volcanic ashes, would combine with the upheaving force to form new land.

'Suppose a shoal, 600 miles in length, to sink 15 feet, and then to remain unmoved for a thousand years; during that interval the growing coral may again approach the surface. Then let the mass be re-elevated 15 feet, so that the original reef is restored to its former position: in this case, the new coral formed since the first subsidence will constitute an island 600 miles long. An analogous result would have occurred if a lava-current 15 feet thick had overflowed the submerged reef. The absence, therefore, of more extensive tracts of land in the Pacific, seems to show that the amount of subsidence by earthquakes exceeds, in that quarter of the globe, at present, the elevation due to the same cause.'*

Another proof also of subsidence derived from the structure of atolls, was pointed out by me in the following passage in all former editions. 'The low coral islands of the Pacific,' says Captain Beechey, 'follow one general rule in having their windward side higher and more perfect than the other. At Gambier and Matilda Islands this inequality is very conspicuous, the weather side of both being wooded, and of the former inhabited, while the other sides are from

* See Principles of Geology, 1st edit., vol. ii. p. 296.

20 to 30 feet under water; where, however, they may be perceived to be equally *narrow* and well defined. It is on the leeward side also that the entrances into the lagoons occur; and although they may sometimes be situated on a side that runs in the direction of the wind, as at Bow Island, ye there are none to windward.' These observations of Captain Beechey accord with those which Captain Horsburgh and other hydrographers have made in regard to the coral islands of other seas. From this fortunate circumstance ships can enter and sail out with ease; whereas if the narrow inlets were to windward, vessels which once entered might not succeed for months in making their way out again. The well-known security of many of these harbours depends entirely on this fortunate peculiarity in their structure.

'In what manner is this singular conformation to be accounted for? The action of the waves is seen to be the cause of the superior elevation of some reefs on their windward sides, where sand and large masses of coral rock are thrown up by the breakers; but there is a variety of cases where this cause alone is inadequate to solve the problem; for reefs submerged at considerable depths, where the movements of the sea cannot exert much power, have, nevertheless, the same conformation, the leeward being much lower than the windward side.*

'I am informed by Captain King, that, on examining the reefs called Rowley Shoals, which lie off the north-west coast of Australia, where the east and west monsoons prevail alternately, he found the open side of one crescent-shaped reef, the Impérieuse, turned to the east, and of another, the Mermaid, turned to the west; while a third oval reef, of the same group, was entirely submerged. This want of conformity is exactly what we should expect, where the winds vary periodically.

'It seems impossible to refer the phenomenon now under consideration to any original uniformity in the configuration of submarine volcanos, on the summits of which we may

* Voyage to the Pacific, &c., p. 189.

suppose the coral reefs to grow; for although it is very common for craters to be broken down on one side only, we cannot imagine any cause that should breach them all in the same direction. But the difficulty will, perhaps, be removed, if we call in another part of the volcanic agency—subsidence by earthquakes. Suppose the windward barrier to have been raised by the mechanical action of the waves to the height of 2 or 3 yards above the wall on the leeward side, and then the whole island to sink down a few fathoms, the appearances described would then be presented by the submerged reef. A repetition of such operations, by the alternate elevation and depression of the same mass (an hypothesis strictly conformable to analogy), might produce still greater inequality in the two sides, especially as the violent efflux of the tide has probably a strong tendency to check the accumulation of the more tender corals on the leeward reef; while the action of the breakers contributes to raise the windward barrier.'*

Previously to my adverting to the signs above enumerated of a downward movement in the bed of the ocean, Dr.

Fig. 164.

Elizabeth or Henderson's Island.

Macculloch, Captain Beechey, and many other writers had shown that masses of recent coral had been laid dry at various heights above the sea-level, in the Red Sea, the islands of the Pacific, and in the East and West Indies. After describing thirty-two coral islands in the Pacific, Captain Beechey mentioned that they were all formed of living coral except one, which, although of coral formation, was raised about 70 or 80 feet above the level of the sea, and was encompassed by a reef of living coral. It is called Elizabeth or Henderson's Island, and is 5 miles in length by 1 in breadth. It has a flat surface, and, on all sides, except the north, is bounded by perpendicular cliffs above 50 feet high, composed entirely of dead coral, more or less

* See Principles of Geol., 1st edit., 1832, vol. ii. p. 293.

porous, honeycombed at the surface, and hardening into a compact calcareous mass, which possesses the fracture of secondary limestone, and has a species of millepore interspersed through it. These cliffs are considerably undermined by the action of the waves, and some of them appear on the eve of precipitating their superincumbent weight into the sea. Those which are less injured in this way present no alternate ridges or indication of the different levels which the sea might have occupied at different periods; but a smooth surface, as if the island, which has probably been raised by volcanic agency, had been forced up by one great subterraneous convulsion.* At the distance of a few hundred yards from this island, no bottom could be gained with 200 fathoms of line.

It will be seen, from the annexed sketch, communicated to me by Lieutenant Smith, of the Blossom, that the trees came down to the beach towards the centre of the island, where there is a break in the cliffs resembling at first sight the openings which usually lead into lagoons; but the trees stand on a steep slope, and no hollow of an ancient lagoon was perceived. Beechey also remarks, that the surface of Henderson's Island is flat, and that in Queen Charlotte's Island, one of the same group, but under water, there was no lagoon, the coral having grown up everywhere to one level. The probable cause of this obliteration of the central basin or lagoon will be considered in the sequel.

That the bed of the Pacific and Indian oceans, where atolls are frequent, must have been sinking for ages, might be inferred, says Mr. Darwin, from simply reflecting on two facts; first, that the efficient coral-building zoophytes do not flourish in the ocean at a greater depth than 120 feet; and, secondly, that there are spaces occupying areas of many hundred thousand square miles, where all the islands consist of coral, and yet none of which rise to a greater height than may be accounted for by the action of the winds and waves on broken and triturated coral. Were we to take for granted that the floor of the ocean had remained stationary from the time when the coral began to grow, we should be compelled

* Beechey's Voyage to the Pacific, &c., p. 46.

to assume that an incredible number of submarine mountains of vast height (for the ocean is always deep, and often unfathomable between the different atolls) had all come tc within 120 feet of the surface, and yet no one mountain had risen above water. But no sooner do we admit the theory of subsidence than this great difficulty vanishes. However varied may have been the altitude of different islands, or the separate peaks of particular mountain-chains, all may have been reduced to one uniform level by the gradual submergence of the loftiest points and the additions made to the calcareous cappings of the less elevated summits as they subsided to great depths.

Openings into the lagoons.—In the general description of atolls and encircling reefs, it was mentioned that there is almost always a deep narrow passage opening into the lagoon, or into the still water between the reef and the shore, which is kept open by the efflux of the sea as the tide goes down.

The origin of this channel must, according to the theory of subsidence before explained, be traced back to causes which were in action during the existence of the encircling reef, and when an island or mountain top rose within it, for such a reef precedes the atoll in the order of formation. Now in those islands in the Pacific, which are large enough to feed small rivers, there is generally an opening or channel in the surrounding coral reef at the point where the stream of fresh water enters the sea. The depth of these channels rarely exceeds 25 feet; and they may be attributed, says Captain Beechey, to the aversion of the lithophytes to fresh water, and to the probable absence of the mineral matter of which they construct their habitations.*

Mr. Darwin, however, has shown, that mud at the bottom of river-courses is far more influential than the freshness of the water in preventing the growth of the polypi, for the walls which enclose the openings are perpendicular, and do not slant off gradually, as would be the case, if the nature of the element presented the only obstacle to the increase of the coral-building animals.

* Voyage to the Pacific, &c., p. 194.

When a breach has thus been made in the reef, it will be prevented from closing up by the efflux of the sea at low tides; for it is sufficient that a reef should rise a few feet above low-water mark to cause the waters to collect in the lagoon at high tide, and when the sea falls, to rush out at one or more points where the reef happens to be lowest or weakest. This event is strictly analogous to that witnessed in our estuaries, where a body of salt water accumulated during the flow issues with great velocity at the ebb of the tide, and scours out or keeps open a deep passage through the bar which is almost always formed at the mouth of a river. At first there are probably many openings, but the growth of the coral tends to obstruct all those which do not serve as the principal channels of discharge; so that their number is gradually reduced to a few, and often finally to one. The fact observed universally, that the principal opening fronts a considerable valley in the encircled island, between the shores of which and the outer reef there is often deep water, scarcely leaves any doubt as to the real origin of the channel in all those countless atolls where the nucleus of land has vanished.

Size of atolls and barrier reefs.—In regard to the dimensions of atolls, it was stated that some of the smallest observed by Beechey in the Pacific were only a mile in diameter. If their external slope under water equals upon an average an angle of 45°, then such an atoll at the depth of half a mile, or 2,640 feet, would have a diameter of two miles. Hence it would appear that there must be a tendency in every atoll to grow smaller, except in those cases where oscillations of level enlarge the base on which the coral grows by throwing down a talus of detrital matter all round the original cone of limestone.

Bow Island is described by Captain Beechey as 70 miles in circumference, and 30 in its greatest diameter, but we have seen that some of the Maldives are much larger.

As the shore of an island or continent which is subsiding will recede from a coral reef at a slow or rapid rate according as the surface of the land has a steep or gentle slope, we cannot measure the thickness of the coral by its distance

from the coast; yet, as a general rule, those reefs which are farthest from the land imply the greatest amount of subsidence. We learn from Flinders, that the barrier reef of north-eastern Australia is in some places 70 miles from the mainland, and it would seem that the calcareous formation is there in progress 1,000 miles long from north to south, with a breadth varying from 20 to 70 miles. It may not, indeed, be continuous over this vast area, for doubtless innumerable islands have been submerged one after another between the reef and mainland, like some which still remain, as, for example, Murray's Islands, lat. 9° 54′ S. We are told that some parts of the gulf enclosed within the barrier are 400 feet deep, so that the efficient rock-building corals cannot be growing there, and in other parts of it islands appear encircled by reefs.

It will follow as one of the consequences of the theory already explained that, provided the bottom of the sea does not sink too fast to allow the zoophytes to build upwards at the same pace, the thickness of coral will be great in proportion to the rapidity of subsidence, so that if one area sinks 2 feet while another sinks 1, the mass of coral in the first area will be double that in the second. But the downward movement must in general have been very slow and uniform, or, where intermittent, must have consisted of a great number of depressions, each of slight amount, otherwise the bottom of the sea would have been carried down faster than the corals could build upwards, and the island or continent would be permanently submerged, having reached a depth of 120 or 150 feet, at which the effective reef-constructing zoophytes cease to live. If, then, the subsidence required to account for all the existing atolls must have amounted to 3,000 or 4,000 feet, or even sometimes more, we are brought to the conclusion that there has been a *slow* and *gradual* sinking to this enormous extent. Such an inference is perfectly in harmony with views which the grand scale of denudation, everywhere observable in the older rocks, has led geologists to adopt in reference to upward movements. They must also have been gradual and continuous throughout indefinite ages to allow the waves and currents of the ocean to operate with adequate power.

The map constructed by Mr. Darwin to display at one view the geographical position of all the coral reefs throughout the globe is of the highest geological interest, leading to splendid generalisations, when we have once embraced the theory that all atolls and barrier reefs indicate recent subsidence, while the presence of fringing reefs proves the land to be stationary or rising. These two classes of coral formations are depicted by different colours; and one of the striking facts brought to light by the same classification of coral formations is the absence of active volcanos in areas of subsidence, and their frequent presence in the areas of elevation. The only supposed exception to this remarkable coincidence at the time when Mr. Darwin wrote, in 1842, was the volcano said to exist in Torres Strait, at the northern point of Australia, placed on the borders of an area of subsidence; but it has been since ascertained that this volcano has no existence.

We see, therefore, an evident connection, first, between the bursting forth every now and then of volcanic matter through rents and fissures, and the expansion or forcing outwards of the earth's crust, and, secondly, between a dormant and less energetic development of subterranean heat, and an amount of subsidence sufficiently great to cause mountains to disappear under the broad face of the ocean, leaving only small and scattered lagoon islands, or groups of atolls, to indicate the spots where those mountains once stood.

On a review of the differently-coloured reefs on the map alluded to, it will be seen that there are large spaces in which upheaval, and others in which depression prevails, and these are placed alternately, while there are a few smaller areas where movements of oscillation occur. Thus if we commence with the western shores of South America, between the summit of the Andes and the Pacific (a region of earthquakes and active volcanos), we find signs of recent elevation, not attested by coral formations, which are wanting there, but by upraised banks of marine shells. Then proceeding westward, we traverse a deep ocean without islands, until we come to a band of *atolls* and encircled islands, including the Dangerous and Society archipelagos,

and constituting an area of subsidence more than 4,000 miles long and 600 broad. Still farther, in the same direction, we reach the chain of islands to which the New Hebrides, Solomon, and New Ireland belong, where fringing reefs and masses of elevated coral indicate another area of upheaval. Again, to the westward of the New Hebrides we meet with the encircling reef of New Caledonia and the great Australian barrier, implying a second area of subsidence.

The only objection deserving attention which has hitherto been advanced against the theory of atolls, as before explained (p. 600), is that proposed by Mr. Maclaren.* 'On the outside,' he observes, 'of coral reefs very highly inclined, no bottom is sometimes found with a line of 2,000 or 3,000 feet, and this is by no means a rare case. It follows that the reef ought to have this thickness; and Mr. Darwin's diagrams show that he understood it so. Now, if such masses of coral exist under the sea, they ought somewhere to be found on *terra firma*; for there is evidence that all the lands yet visited by geologists have been at one time submerged. But neither in the great volcanic chain, extending from Sumatra to Japan, nor in the West Indies, nor in any other region yet explored, has a bed or formation of coral even 500 feet thick been discovered, so far as we know.'

When considering the objection, it is evident that the first question we have to deal with is, whether geologists have not already discovered calcareous masses of the required thickness and structure, or precisely such as the upheaval of atolls might be expected to expose to view? We are called upon, in short, to make up our minds both as to the internal composition of the rocks that must result from the growth of corals, whether in lagoon islands or barrier reefs, and the external shape which the reefs would retain when upraised gradually to a vast height,—a task by no means so easy as some may imagine. If the reader has pictured to himself large masses of entire corals, piled one upon the other, for a thickness of several thousand feet, he unquestionably mistakes altogether the nature of the accumulations now in progress.

* Scotsman, Nov. 1842, and Jameson's Edin. Journ. of Science, 1843.

In the first place, the strata at present forming very extensively over the bottom of the ocean, within such barrier reefs as those of Australia and New Caledonia, are known to consist chiefly of horizontal layers of calcareous sediment, while here and there an intermixture must occur of the detritus of granitic and other rocks brought down by rivers from the adjoining lands, or washed from sea-cliffs by the waves and currents. Secondly, in regard to atolls, the stone-making polypifers grow most luxuriantly on the outer edge of the island, to a thickness of a few feet only. Beyond this margin broken pieces of coral and calcareous sand are strewed by the breakers over a steep seaward slope, and as the subsidence continues, the next coating of live coral does not grow vertically over the first layer, but on a narrow annular space within it, the reef, as was before stated (p. 603), constantly contracting its dimensions as it sinks. Thirdly, within the lagoon the accumulation of calcareous matter is chiefly sedimentary, a kind of chalky mud derived from the decay of the softer corallines, with a mixture of calcareous sand swept by the winds and waves from the surrounding circular reef. Here and there, but only in partial clumps, are found living corals, which grow in the middle of the lagoon, and mixed with these and with fine mud and sand, a great variety of shells, and fragments of testacea and echinoderms.

We owe to Lieutenant Nelson the discovery that in the Bermudas the calcareous mud resulting from the decomposition of the corals and nullipores resembles closely, but not microscopically, the ordinary white chalk of Europe,* and this mud is carried to great distances by currents, and spread far and wide over the floor of the ocean. We also have opportunities of seeing in upraised atolls, such as Elizabeth Island, Tonga, and Hapai, which rise above the level of the sea to heights varying from 10 to 80 feet, that the rocks of which they consist do not differ in structure or in the state of preservation of their included zoophytes and shells from some of the oldest limestones known to the geologist. Captain Beechey remarks that the dead coral in Elizabeth's

* Trans. Geol. Soc. London, 2d series, vol. v.

Island is 'more or less porous and honeycombed at the surface, and hardening into a compact rock which has the fracture of *secondary limestone*.'*

The island of Pulo Nias, off Sumatra, which is about 3,000 feet high, is described by Dr. Jack as being overspread by coral and large shells of the *Chama* (*Tridacna*) *gigas*, which rest on quartzose and arenaceous rocks, at various levels from the sea-coast to the summit of the highest hills.

The cliffs of the island of Timor in the Indian Ocean are composed, says Mr. Jukes, of a raised coral reef abounding in *Astræa*, *Mœandrina*, and *Porites*, with shells of *Strombus*, *Conus*, *Nerita*, *Arca*, *Pecten*, *Venus*, and *Lucina*. On a ledge about 150 feet above the sea, a Tridacna (or large clam shell), two feet across, was found bedded in the rock with closed valves, just as they are often seen in barrier reefs. This formation in the islands of Sandlewood, Sumbawa, Madura, and Java, where it is exposed in sea cliffs, was found to be from 200 to 300 feet thick, and it is believed to ascend to much greater heights in the interior. It has usually the form of a 'chalk-like' rock, white when broken, but in the weathered surface turning nearly black.†

It appears, therefore, premature to assert that there are no recent coral formations uplifted to great heights, for we are only beginning to be acquainted with the geological structure of the rocks of equatorial regions. Some of the upraised islands, such as Elizabeth and Queen Charlotte, in the Pacific, although placed in regions of atolls, are described by Captain Beechey and others as flat-topped, and exhibiting no traces of lagoons. In explanation of the fact, we may presume that, after they had been sinking for ages, the descending movement was relaxed; and while it was in the course of being converted into an ascending one, the ground remained for a long season almost stationary, in which case the corals within the lagoon would build up to the surface, and reach the level already attained by those on the margin

* Beechey's Voyage, vol. i. p. 45.

† Paper read to Brit. Assoc. Southampton, 1846. Dr. Duncan informs me that these coral cliffs are now known to belong to the Tertiary Period.

of the reef. In this manner the lagoon would be effaced, and the island acquire a flat summit.

It may, however, be thought strange that many examples have not been noticed of fringing reefs uplifted above the level of the sea. Mr. Darwin, indeed, cites one instance where the reef preserved, on dry land in the Mauritius, its peculiar moat-like structure; but they ought, he says, to be of rare occurrence, for in the case of atolls or of barrier or fringing reefs, the characteristic outline must usually be destroyed by denudation as soon as a reef begins to rise; since it is immediately exposed to the action of the breakers, and the large and conspicuous corals on the outer rim of the atoll or barrier are the first to be destroyed and to fall upon the bottom of vertical and undermined cliffs. After slow and continued upheaval a wreck alone can remain of the original reef. If, therefore, says Mr. Darwin, 'at some period as far in futurity as the secondary rocks are in the past, the bed of the Pacific with its atolls and barrier reefs should be converted into a continent, we may conceive that scarcely any or none of the existing reefs would be preserved, but only widely spread strata of calcareous matter derived from their wear and tear.*

When it is urged in support of the objection before stated (p. 612) that the theory of atolls by subsidence implies the accumulation of calcareous formations 2,000 or 3,000 feet thick, it must be conceded that this estimate of the minimum thickness of the deposits is by no means exaggerated. On the contrary, when we consider that the space over which atolls are scattered in Polynesia and the Indian oceans may be compared to the whole continent of Asia, we cannot but infer from analogy that the differences in level in so vast an area have amounted, antecedently to subsidence, to 5,000 or even a greater number of feet. Whatever was the difference in height between the loftiest and lowest of the original mountains or mountainous islands on which the different atolls are based, that difference must represent the thickness of coral which has now reduced all of them to one level. Flinders, therefore, by no means exaggerated the

* Letter to Mr. Maclaren, Scotsman, 1843.

volume of the limestone, which he conceived to have been the work of coral animals; he was merely mistaken as to the manner in which they were enabled to build reefs in an unfathomed ocean.

But is it reasonable to expect, after the waste caused by denudation, that calcareous masses, gradually upheaved in an open sea, should retain such vast thicknesses? Or may not limestones of the cretaceous and oolitic epochs, which attain in the Alps and Pyrenees a thickness of 3,000 or 4,000 feet, and are in great part made up of coralline and shelly matter, present us with a true geological counterpart of the recent coral reefs of equatorial seas? I am also reminded by Dr. Duncan that the Miocene coral formations of Jamaica are enormously thick.

Before we attach serious importance to arguments founded on negative evidence, and opposed to a theory which so admirably explains a great variety of complicated phenomena, we ought to remember that the upheaval to the height of 4,000 feet of atolls in which the coralline limestone would be 4,000 feet thick, implies, first, a slow subsidence of 4,000 feet, and, secondly, an elevation of the same amount. Even if the reverse or ascending movement began the instant the downward one ceased, we must allow a great lapse of ages for the accomplishment of the whole operation. We must also assume that at the commencement of the period in question, the equatorial regions were as fitted as now for the support of reef-building zoophytes. This postulate would demand the continuance of a complicated variety of conditions throughout a much longer period than they are usually persistent in one place.

To show the difficulty of speculating on the permanence of the geographical and climatal circumstances requisite for the growth of reef-building corals, we have only to state the fact that there are no reefs in the Atlantic, off the west coast of Africa, nor among the islands of the Gulf of Guinea, nor at St. Helena, Ascension, the Cape Verds, or St. Paul's. With the exception of Bermuda, there is not a single coral reef in the central expanse of the Atlantic, although in some parts the waves, as at Ascension, are charged to excess with cal-

careous matter. The capricious distribution of coral reefs is probably owing to the absence of fit stations for the reef-building polypifers, other organic beings in those regions obtaining in the great struggle for existence a mastery over them. Their absence, in whatever manner it be accounted for, should put us on our guard against expecting upraised reefs at all former geological epochs, similar to those now in progress.

Lime, whence derived.—Dr. Macculloch, in his System of Geology, Vol. I. p. 219, expressed himself in favour of the theory of some of the earlier geologists, that all limestones have originated in organised substances. If we examine, he says, the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the siliceous and argillaceous rocks than in the secondary; and this may have some connection with the rarity of testaceous animals in the ancient ocean. He further infers, that in consequence of the operations of animals, 'the quantity of calcareous earth deposited in the form of mud or stone is always increasing; and that as a secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depths of the sea, which may exceed the last in the proportion of its calcareous strata.'

The comparative scarcity of carbonate of lime in the oldest rocks insisted upon in the passage here cited, was chiefly deduced from observations on the geology of Scotland, with which Dr. Macculloch was familiar. Of late years our Canadian surveyors have taught us that the most ancient series of rocks yet discovered in the earth's crust, the Laurentian, contain vast formations of limestone; and the theory of metamorphic action, by which the ancient fossiliferous rocks have been transformed into those of the crystalline series (see Vol. I. p. 138), puts us on our guard against expecting any exact correspondence in the quantity of particular minerals, such as lime, contained in the hypogene, as contrasted with the incumbent formations.

We observe that, in volcanic countries, there is an enormous evolution of carbonic acid, either free, in a gaseous form, or mixed with water; and the springs of such dis-

tricts are usually impregnated with carbonate of lime in great abundance. No one who has travelled in Tuscany, through the region of extinct volcanos and its confines, or who has seen the map constructed by Targioni (1827), to show the principal sites of mineral springs, can doubt, for a moment, that if this territory was submerged beneath the sea, it might supply materials for the most extensive coral reefs. The importance of these springs is not to be estimated by the magnitude of the rocks which they have thrown down on the slanting sides of hills, although of these alone large cities might be built, nor by a coating of travertin that covers the soil in some districts for miles in length. The greater part of the calcareous matter passes down in a state of solution to the sea, and in all countries the rivers which flow from chalk and other marly and calcareous rocks carry down vast quantities of lime into the ocean. Lime is also one of the component parts of augite and other volcanic and hypogene minerals, and when these decompose it is set free, and may then find its way in a state of solution to the sea.

The lime, therefore, contained generally in sea-water, and secreted so plentifully by the testacea and corals of the Pacific, may have been derived either from springs rising up in the bed of the ocean, or from rivers fed by calcareous springs, or impregnated with lime derived from disintegrated rocks, both volcanic and hypogene. If this be admitted, the greater proportion of limestone in the more modern formations as compared to the most ancient, will be explained, for springs in general hold comparatively a small quantity of siliceous and still less of aluminous matter in solution, but they are continually subtracting calcareous matter from the inferior rocks. The constant transfer, therefore, of carbonate of lime from the lower or older portions of the earth's crust to the surface, must cause at all periods, and throughout an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer as contrasted with the older formations.

CONCLUDING REMARKS.

In the concluding chapters of the First Book, I examined in detail a great variety of arguments which have been adduced to prove the distinctness of the state of the earth's crust at remote and recent epochs. Among other supposed proofs of this distinctness, the dearth of calcareous matter, in the ancient rocks above adverted to, might have been considered. But it would have been endless to attempt to reply to all the objections urged against those who would represent the course of nature at the earliest periods as resembling in all essential circumstances the state of things now established. We have seen that a strong desire has been manifested to discover in the ancient rocks the signs of an epoch when the planet was uninhabited, and when its surface was in a chaotic condition and uninhabitable. The opposite opinion, indeed, that the oldest of the rocks now visible may be the last monuments of an antecedent era in which living beings may already have peopled the land and water, has been declared to be equivalent to the assumption that there never was a beginning to the present order of things.

With equal justice might an astronomer be accused of asserting that the works of creation extended throughout *infinite* space, because he refuses to take for granted that the remotest stars now seen in the heavens are on the utmost verge of the material universe. Every improvement of the telescope has brought thousands of new worlds into view; and it would, therefore, be rash and unphilosophical to imagine that we already survey the whole extent of the vast scheme, or that it will ever be brought within the sphere of human observation.

But no argument can be drawn from such premises in favour of the infinity of the space that has been filled with worlds; and if the material universe has any limits, it then follows, that it must occupy a minute and infinitesimal point in infinite space.

So if, in tracing back the earth's history, we arrive at the

monuments of events which may have happened millions of ages before our times, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remain unshaken; and if the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitesimal portion of eternity.

It has been argued, that, as the different states of the earth's surface, and the different species by which it has been inhabited, have all had their origin, and many of them their termination, so the entire series may have commenced at a certain period. It has also been urged, that, as we admit the creation of man to have occurred at a comparatively modern epoch—as we concede the astonishing fact of the first introduction of a moral and intellectual being—so also we may conceive the first creation of the planet itself.

I am far from denying the weight of this reasoning from analogy; but although it may strengthen our conviction, that the present system of change has not gone on from eternity, it cannot warrant us in presuming that we shall be permitted to behold the signs of the earth's origin, or the evidences of the first introduction into it of organic beings. We aspire in vain to assign limits to the works of creation in *space*, whether we examine the starry heavens, or that world of minute animalcules which is revealed to us by the microscope. We are prepared, therefore, to find that in *time* also the confines of the universe lie beyond the reach of mortal ken. But in whatever direction we pursue our researches, whether in time or space, we discover everywhere the clear proofs of a Creative Intelligence, and of his foresight, wisdom, and power.

As geologists, we learn that it is not only the present condition of the globe which is suited to the accommodation of myriads of living creatures, but that many former states also were adapted to the organisation and habits of prior races of beings. The disposition of the seas, continents, and islands, and the climates, have varied; the species likewise have been changed; and yet they have all been

so modelled, on types analogous to those of existing plants and animals, as to indicate, throughout, a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical enquiries, or even of our speculations, appears to be inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being.

GENERAL INDEX.